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FOOD AND CHARACTER

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BY

LOUIS BERMAN, M.D.

‘Tell me what you eat, and I will tell you what you are.’
BRILLAT-SAVARIN (1825)

‘Man is what he eats.’
LUDWIG FEUERBACH (1850)

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TO

PROFESSOR WILLIAM J. GIES

IN WHOSE CLASSES I FIRST LEARNED OF BIOCHEMISTRY

CONTENTS

INTRODUCTION

Food and Morals

IT was the great French philosopher of the cuisine, Brillat-Savarin, who said in his book on the ' Philosophy of Taste ' : ' The destiny of nations depends upon what and how they eat.' He summarized belief in the effect of food on character. And to this day various fads and quackeries have flourished upon the superstitions of the ages regarding diet and personality.

But how is a man made by what he eats and drinks ? And why is he so much of what he consumes ? And how are the chemicals of food formed into the mysterious processes of personality and character ?

The problem does not have much of a scientific history. Haller, renowned physiologist of the eighteenth century, experimented on himself. He studied the effect of diet upon his temperamental reactions. He took wine and meat together, then alternately. Then he abstained altogether, and found there was no change in himself. Sieland reversed the procedure by studying the secretions and excretions of individuals of obviously different temperaments. He used the ancient classification of the phlegmatic and choleric types. As their methods and concepts were crude, their negative results were to be expected.

Modern biochemistry, dating from Lavoisier, advanced by Liebig and Magendie, and so splendidly developed by subsequent workers, has discovered that all living things have pretty much the same chemical composition. Also, it has learned, that all animals, including human beings, have the same chemical make-up as the foods they eat. For living protoplasms feed upon what once were also living protoplasms—which are everywhere alike. Accordingly, it has been assumed that a diet could be constructed which would be perfect for any human being. Take the ideal number of calories, the ideal

amount of protein, fat, carbohydrate, salts, and vitamins as well. Then add the psychological adjuncts of flavour and variety. Upon that basis, it has been supposed, the prize human being, from the nutritional and therefore basic standpoint, could be artificially manufactured. This is the doctrine of the ideal standard normal diet.

Can Human Beings be Reared as Prize Animals ?

In the laboratory, white rats, as measured by weight, degree of development, types of behaviour, character of coat, and capacity for reproduction, have been raised on a standard ideal diet. And the differences between differently nourished white rats, under perfectly controlled experimental conditions, are obvious to the most casual observer.

But can prize animals be thus created ? Farm animals have been brought to their high standards by feedings which have paid much attention to the individuality of the creature. Breeders claim that they have successfully raised prize dogs and cats to their superb blue-ribbon condition by care of each individual need. And among human beings, by experiences in clinical practice as well as by the results of numerous laboratory researches, I have become convinced that the *current doctrine of a standard diet is a mistake.*

No two human beings can or should be fed alike if our purpose is to put them into a state of ideal or optimal health. Nowhere, in fact, it would seem, should greater homage be paid to individuality than in the matter of what is put into the individual. Yet text-books and articles on diet persist in writing of the ‘ normal diet ’. There is no such commodity as a ‘ normal diet ’ in the sense that it is a diet making for the maintenance of normality. There is an average, customary, adequate diet. This is an habitual ingestion of foods which enable the individual to go along the usual tenor of his ways, without his becoming obviously starved, undernourished, or ill. But there are very few food programmes specifically planned and scientifically achieved for the special needs of the particular individual, except in cases of gross disease.

It has been contended that the ‘ normal ’ individual, when left to his own choices, will select the food best suited to his individual peculiarities and the demands of his own organism. And as a matter of fact, it has been shown that infants, when permitted to choose for themselves, pick the foods that make

them grow better than those fed on the strictest supervised régimes. Animals, also, when allowed to select, will take the foods they need. Man, however, again is much more complex than either baby or animals. His taste, like his sense of his own needs, becomes perverted early in his development. It is because the system of culture under which he generally lives ruthlessly insists from childhood upon so many renunciations of instinct and upon homage to family and group conformities and necessities.

Can the Voice of Appetite be Trusted?

Few grown persons, therefore, may be said to be able to trust their own instincts and cravings as to what to eat and drink. Ordinarily, most people consume enough, and, in this country, probably more than enough, for their requirements of energy. The custom of the family, the friends, the social class dictates the quality and kinds of foods, and the order in which they are ingested. These, it is said, are more or less determined by the experience of the race or the local tradition, which provide the individual with a certain amount of empirical, rule-of-thumb nutritive safety. In the same community, though, one may see individuals or families living upon the most diverse dietetic combinations. Besides, methods of preparation of food are so different nowadays that, even if the suggestions of appetite and taste were reliable, the modes of satisfying them might be said to be tainted at the source.

Moreover, one may doubt that the spontaneous cravings for certain foods are necessarily to be respected as the arbiters of what one should eat. It is true that one who is thirsty seeks water directly, although even that generalization is vitiated by observation of the many who turn to alcohol rather than to the dihydrol, that is, water. A whole series of conditions exists due to inadequate or poor selection of foods. Often they are so mild as to pass unnoticed for years because they do not cause pain or gross incapacity. In some the Voice of Nature spurs the individual to eat and drink the very foods that are most injurious.

In Froehlich's Disease, for instance, the individual, who suffers from an obesity due to deficient function of the pituitary gland, is possessed of an almost uncontrollable desire for sweets, in spite of the fact that it is the sugars which are converted into more and more fat in the body, because he is

unable to burn them. This may be the most distressing feature of the condition.

Similar obsessive cravings or aversions may exist for meat, salt, vegetables, fruits, acids, water—in fact, any food—under the most paradoxical conditions. Aversions are generally more trustworthy than cravings, as, for example, the aversion to fats in deficiency of the adrenal glands. In short, both as a victim of culture and as a creature of the complexities in his body chemistry, man must regard critically the decrees of instinct, habit, and craving when he thinks of feeding himself rationally.

And there is now, more than ever, no dearth of voices urging him to feed himself correctly. Thousands, realizing that they lack instruction on how to nourish themselves, seek information. Consequently, one hears much misinformed assertion concerning calories and fuel values, vitamins and the trend toward salads, dietary safety and the religion of raw foods. A plethora of articles in magazines, books, scholastic courses seek to educate the individual in the new dietary laws discovered by science. For the comic columnist and cartoonist, the situation is relieved only by the announcement of the separation of a new vitamin responsible for some function in the body.

Ford on Food

Even Henry Ford, whose opinion on any and every subject is listened to with such profound respect because he has superintended the making and selling of so many cheap automobiles, has recently delivered himself of a manifesto on the subject. Under the caption of ‘ Diet and Morals ’, the following editorial appeared in the *New York State Journal of Medicine* (May 15, 1929, volume 29, page 635) :

> What the editor of the *New York State Journal of Medicine* says about health is seldom considered to be news, owing to quantity production, but what Henry Ford says about any phase of health attracts immediate notice, for a time. The *New York Times* of May 10 contains a report in which Mr. Ford suggests that dieting should be taught by clergymen because of its effect on character and morals.

Turning to the interview, the following is an interesting quotation :

'For a long time now the clergy has been teaching people to be good. They cannot do this and disregard the habits of living. Health is a condition that affects everything. Instead of cluttering up religion with a lot of things that do not belong to it, why does not the clergy teach people how to eat? There are such great changes of mental attitude to be obtained by correct habits of diet that it would pay the clergy to attend to the commoner and more respectable habits, such as eating, than to some of the results of bad eating.

'Most wrong acts committed by men are the result of wrong mixtures in the stomach. Booze is not food, but people put it into their stomachs, and you know what frequently happens. Dope—wrong foods—wrong mixtures of good food—Crime, if that is what you want to call it, comes from wrong mixtures.'

'Granting that, Mr. Ford, how can ministers be expected to give intelligent discussions on food values? How can they know?'

'They can learn. They can first find out for themselves by experiment. Religion always had a lot to say about eating—you have only to look into the Bible to see that. Ministers can learn, or if they don't want to learn, they can invite people who understand into the pulpits.'

'You mean, instead of talking so much about religion, you would have ministers—or persons expert in the subject—discuss food values?'

'I did not say "instead of religion"; this is a part of religion. In fact, you cannot have a thorough-going complete religion without it. You may have a system of ideas, but not a complete system of life. And after all, the life is the religion.'

'Then you think it could be taught?'

'Yes, and with great advantages. First discover the vital connexion between food and attitudes of mind, between food and the energies of mind and of body; then experience the benefits of a proper course.'

In the same interview article, Dr. Royal S. Copeland, United States Senator from New York and former Health Commissioner of the City of New York, is said to have remarked, as he finished reading the Fordian remarks:

'Uninformed persons will smile at Mr. Ford's conclusions. Doctors won't. Nor will persons who have had experience in the subject. There isn't any doubt but that we are what we are because of what we eat.

'I agree with Mr. Ford that the clergy can have no greater purpose than teaching people how to live. I agree with him when he says values in right living should be taught from the pulpits. It is a proved fact that an individual who is well-nourished will

have functions which are normal. If his functions are normal, he is likely to think straight and likely to live straight.

' However, I do not believe Mr. Ford has gone far enough in the expression of the thought. I am much more in favour in taking the subject of proper eating beyond the church and into the schools. For quite a number of years I have been tremendously interested in the subject of school lunches—and what goes into them. There is far more than mere feeding. An informed person should tell the children why they are getting certain foods and certain balances. This should be done, not only for the purpose of education of the child, but also for the purpose of educating the parents.'

' Is it possible for wardens of penal institutions to straighten out the lives of their prisoners by changing or improving food balances ? '

' It is not only possible—it is very probable. The fact that a child grows into maturity and into trouble with the laws because of malnutrition doesn't prevent that child, as a man, reorganizing his life through his intestinal tract. . . .

' . . . Mr. Ford, at sixty-five years of age, is in fine health. He is frugal in his eating. He has learned that his system requires certain combinations that it may function properly. All men are not built alike. Some men may require more food ; some may require less ; but the vast majority of persons eat far more than they need—and most persons indulge in the wrong mixtures.

' One proof of that is found in the crowded conditions of our jails, and our reformatories and prisons. Speaking from a medical viewpoint, there is no doubt about it. I do not quite agree with the sweep of Mr. Ford's statement that, " Some day people will learn how to eat and there won't be any more hospitals." But it is so very close to the truth that I have no quarrel with it.'

A few months after this interview, the honorary title of M.D. was conferred on Mr. Ford by the Interstate Medical Assembly.

Thus say Automobileer Ford and Senator Copeland. Though they are not the opinions of so-called experts or of high priests in institutions devoted to dietetics, they are worthy of attention as symptoms of an important movement. In referring clergymen to the Book of Genesis, Mr. Ford might have mentioned the profound transformation of character produced in their original ancestors by partaking of a certain variety of fruit at the instigation of Satan. What a chance, in perfecting their personalities, Adam and Eve missed, when they failed to force themselves to take that other fruit which might have made them the equals of gods and angels !

By omitting to list apples and milk as the universal panacea in the feeding of children, Senator Copeland proved himself acquainted with some of the intricacies of the field.

Superstitions about Meat

As characteristic of another attitude is that of Clendening on Meat, in the May, 1929, number of the *American Mercury*. Clendening established his reputation as an authority by a book concerning the Human Body, in which he asserted that the medical profession can do nothing for the genuine prevention of disease or for the actual prolongation of life.

In the article mentioned, accordingly, he preaches the doctrine of *laissez-faire* as regards the eating of meat. For knowledge about the relations of uric acid metabolism and the consumption of meat, he recommends the reader to a paper published in 1905. This was made completely out of date in 1913. In that year, the first accurate method for the determination of the uric acid content of the blood was introduced by Folin and Denis. Since then, using this method, an enormous amount of valuable informing work has been done concerning the uric acid in the body during both health and disease.

It would not be worth while mentioning Clendening if his illogical deductions were not characteristic of those of many others. For example, he argues that, while it is true that uric acid is increased in the blood and urine when there is abundant meat in the diet, uric acid is present in the blood and urine even when no meat at all is eaten. Therefore, he says, there is no relation between the eating of meat and disturbances of the uric acid metabolism of the body, which is manifestly absurd.

Such ignoring of all the overwhelming weight of evidence on the importance of individual differences in diet is common. It is not even as well informed as the experience of the ages: as is crudely exemplified in the fundamental principle of folklore that what is one man's meat is another man's poison.

But apart from all one-sided views, whether they be inordinately propagandist, like Ford's, or extremely ill-informed, like Clendening's, there can be no doubt that individual differences in food requirements have everything to do with health, and therefore with personality and character, behaviour and morals. As regards health, it has been an

ancient tradition in the history of medicine. And from Hippocrates to Cornaro, and from Cornaro to Fletcher, the record presents the most interesting instances of disease averted and life prolonged by changes in dietary habits. These form the vague background upon which medical men project their experiences of digestive indiscretions (as they call them) in relation to transformations of mood, temperament, and mentality in general.

The Triumphs of Special Diets for Children

In the last generation a great demonstration has been justly emphasized by the exponents of preventive medicine. They point out the value of their activities in the increase of the life-span of the average individual that has come as a result of their efforts. Undoubtedly, that non-existent entity, the statistical norm or the average person, lives much longer than he used to, in the communities of Western civilization, at any rate. Upon analysis, though, this striking effect of modern medicine upon morbidity and longevity turns out to be essentially a tremendous decrease in infant mortality. Only one generation ago as much as 25 per cent, or one out of four, would have died because of the ignorance or carelessness of their parents in the matter of the right food for them.

To-day, mothers are taught how to feed their babies properly. By a campaign of education against unconscious infanticide, a number of children who might not have survived during the first year, because of various conditions, traceable, directly or indirectly, to bad feeding, have been saved. But it is not only in the first year that food education has played a dominant role in the prolongation of life. Systematically and incessantly, pediatrists have advised parents concerning the importance of correct and adequate nutrition during the second and third years, and, indeed, all through childhood. Parents have been impressed with the fact that there should be periodic examinations and overhaulings of their children's diet and state of nutrition. Thus has been promoted the best conditions of growth for the child, which is its social function! In consequence, the new generation has been maintained in the best of health and possessed of a maximum of resistance to disease.

In the first years of the movement, emphasis was laid upon the absolute value of sterility in the food. The prime object

was to provide milk freed of pathogenic bacteria as much as possible. It was then found that the process of sterilizing harmed the milk as well as the germs. Even pasteurization affected its constituents, rendering them less fit for the optimal growth and nutrition of the baby. Fresh, raw, aseptic milk was provided. At the same time, also, propaganda for the continuance of breast-milk feeding became active.

Then the most acute specialists discovered that there were different types of children who had to be fed according to the demands of their special constitutional needs and capacities. They attempted to imitate breast milk by mixing cow's milk with other ingredients (fats, sugar, starches, and protein). Again it was found that no such simple principle could be applied indiscriminately. Each child, as a problem in itself, had to be treated as the unique phenomenon it was in the domains of physiology as well as of psychology. All in all, a great deal was learned and applied to make childhood what it is now, the least dangerous and the most healthful of all the life periods. Whereas a generation ago the reverse was true.

It is, therefore, legitimate to say that the education of parents has prolonged the life and health of children. When it comes to the other life periods, though, the story becomes different. Adolescents, adults, the middle-aged, and the elderly are generally left to their own devices in the matter of diet. And the result is still apparent in their health and longevity records. Between the ages of fourteen and eighteen, for instance, there is a marked increase in tuberculosis in girls as compared with youths during the same age period. Circumstantial evidence makes it strongly probable that certainly an important percentage of this increase is due to malnutrition self-induced by wrong feeding, originating in the desire to maintain a *svelte* figure.

Now, as a matter of fact, it is possible to reduce weight scientifically on a balanced food schedule without any danger whatsoever to the health and disease resistance of the individual. It is also possible to cause a redistribution of body fat so that it will be deposited where it properly belongs. It can be accomplished by adequately supervised glandular treatment without producing any degree of malnutrition whatever. Not acquainted with that possibility, these adolescents, by self-experimentation, pave the way for some chronic disease like tuberculosis or pernicious anaemia.

The Degeneration called Middle Age

It has been estimated that in the United States there are about three million people who are seriously sick. About half of these die annually. These figures should be regarded in perspective to the fact that at least half the population suffers from significant, premature, preventable physical imperfections. Their effects are shown in the thirties, forties, and fifties. These are the so-called degenerative diseases, which, potentially transmitted by the genes and the chromosomes, fail to be prevented, as they could be, by the adequate utilization of knowledge of diet and the protective action of the endocrine glands. So that men and women are saved in their infancy only to die in the prime of their lives. That is one of the ironic tragedies of our enlightened civilization.

Now, why this overwhelming stupidity? McCollum is worth quoting as an answer:

> All would agree that we must attribute our physical deterioration to the subjection of the human to new and unfavourable conditions, but differences of opinion exist as to the relative importance of these. The sedentary life within houses instead of out-of-doors, the wearing of clothing instead of exposing the skin to the weather with its changing conditions, the eating of soft food instead of raw, coarse food, the debilitating effect of certain climates, the preservation of weaklings through nursing, the burden of responsibilities of civilized life, both mental and moral, and the failure to care for the hygiene of the mouth are among the causes most prominent. Doubtless each of these plays its part in contributing to place civilized man in many parts of the world in his present unenviable position with respect to health. It can now, however, be asserted with assurance that the chief factor responsible for human deterioration in recent times is not included in the above list. The chief factor lies in the unwise choice of food.

Although biased, he has shown his judgement not too overweighted by being a specialist in nutrition.

Every one should work for the establishment of the standards of Samuel Butler's *Erewhon*, where to be ill was a crime. No period of life stands out so emphatically as most incriminated from the food standpoint as middle age. It is a fact that even if the average life has been markedly prolonged in the last twenty-five years, there has developed contemporaneously an augmented morbidity and mortality of the middle-aged.

More people suffer from heart and kidney, blood vessel, and nervous disease of the type classified as degenerate than was the case a generation ago. People change earlier and at a more rapid rate in our civilization, in spite of all the agencies of preventive medicine. It is true that many more children are kept alive; but when those children attain or pass maturity, they do not live as long as their ancestors. Or, if they do live on, it is as semi-incapacitated, morose invalids.

The Malnutrition called Obesity

Undoubtedly, a number of contributory causes determine the increased disease and death-rate of the middle-aged. But to the biological chemist, the underlying condition is a disturbance of metabolism. There is a disturbance of the general chemistry of the blood and the cells based upon wrong feeding. This is the malnutrition of the fattening middle-aged.

One of the commonest manifestations of disturbances in body chemistry is the tendency to put on weight as the individual grows older. That tendency to store fat finally becomes the obvious deformity known as obesity. It is due to piling up of the effects of wrong feeding over a period of years.

In the last few years the problem of excess fat has become more and more important for an increasing number of people. From both the public health and the aesthetic standpoints, the subject has become one of paramount interest. For years surgeons have realized that it is much more dangerous to operate on fat people. Physicians have known that an obese person attacked by pneumonia, influenza, typhoid fever, or any other infectious disease had a poorer prognosis, less of a chance to recover than the normally weighted.

Also, certain insurance statisticians, such as Dublin, have proved definitely that obesity is associated with a greater liability to diseases like diabetes, gall stones, high blood pressure, and other organic degenerative diseases. Recently, the evidence from the analyses of hundreds of thousands of policyholders has become overwhelming, that obesity (overweight) is the metabolic disease of middle age, *par excellence.*

Fat, unoxidized food, material that has not been properly burned in the process of body chemistry, collects under the skin, in the muscles and bones, around the intestines, the heart, and the kidneys. It may penetrate the very wall of the heart

and block the action of its muscles. A higher and higher blood pressure becomes associated with the strain on the heart and the kidneys, provoking further wear and tear of all the tissues.

All this points to the striking relation between this form of fatty malnutrition in the middle-aged and their degeneration. But there are other malnutritions. Other abnormal chemistries contribute their quota to the degenerations of middle age, making it the shortest-lived of the series from infancy to senility. Slight mistakes or imbalances in diet maintaining their action for years may first voice their effects during that period as diseases of the blood, like pernicious anaemia. It is significant that the life insurance companies now adjust their premiums to the degree of malnutrition, as measured by overweight, as well as underweight, of applicants for policies.

There can be no doubt that during the critical middle-age period, health could be materially heightened by proper attention to individual food requirements. Character and conduct changes of the middle-aged could be similarly controlled. But, as in the universal predicaments of the problems of conduct and character, there is no golden rule. For as Bernard Shaw has said: 'Do not do unto others as you would that they do unto you, for their tastes may not be the same.' For one man a vegetarian diet, for another, much flesh food, for a third, meals mainly fruitarian, and for a fourth, the most varied mixture may be the ideal.

It would be well if indigestion or malnutrition were treated as misdemeanours instead of as ailments to be pampered or sympathized with. Some attention might then be paid to the far-reaching connexions between the chemicals so carelessly introduced into the body as food, and the laws of behaviour and character.

Food Habits among Different Peoples

Sir Frederick Gowland Hopkins has stated that, in all history, no nation has ever been fed on a properly balanced diet. No local menus are ever complete. The custom of the country is most to be blamed.

Nothing is more interesting than the study of the food habits and customs of different peoples at various periods of their history. Among the Jews, as is well known, dietetic

habits have been the subject of religious regulation. How much the strict hygiene of food preparation, in the way of preventing contamination of it by bacteria and parasites, has improved the hardihood of the race is difficult to say. How much have the specific food prohibitions and directions had to do with their survival ? There can be no question, in view of what we know about food, that they played an important part.

Many other causes have been discussed in reviewing the downfall of various civilizations—the culture that was Egypt, the glory that was Greece, and the pomp that was Persia. Suggestions concerning changes in dietary habits have been inevitable. Several students of diet have analysed in detail the diet of various races and nations and have shown wherein they were lacking.

The Greeks of the Periclean Age, it has been recorded, lived upon bread and olive oil, wine and figs. In addition, they favoured salads and fruits. Onions and asparagus, peas and beans, are frequently mentioned as the treats that graced their festive herbivorous boards. According to Gerard, the Spartans ate watercress with their bread, convinced that it increased their wisdom. There is an old proverb to the effect that to learn wit one should eat watercress.

The food was more varied, but great emphasis on fresh fruits and vegetables was placed among the pagan Italians of the Renaissance, the Italy of Michelangelo and that materialistic Pope who said, ' What profit has not the fable of Christ brought us ! '

It is possible that certain food abstentions have been just as effective as indulgences in moulding the physique and character of a people. Among certain primitives, such as the American Indians, the doctrines of totemism produced a religious abhorrence of certain foods. A man's totem was believed to be somehow akin to his own body and soul, and to partake of it was therefore as repugnant as the practice of cannibalism. These might be plants and vegetables, birds or beasts. In consequence, specific forms of flesh, fish, fowl, or fruits may be forbidden. Thus there are tribes who abstain from eating pears or strawberries, onions or asparagus, the goose or the deer, and so on. Among the Jews, abstention from pork probably has a totemistic origin. The Greeks and the Romans considered the pig a delicacy. They relished roast pig, like the Chinese.

Totemistic abstention may also be connected with the idea that the qualities of the eaten pass into the eater.

In our own times, there has been a definite attempt to trace the degeneration of the population in modern England to its food. An astounding number of physical defects were found in the English people in the course of the examinations made during the World War. It is quite likely that a change in the quantity and quality of food accompanying the Industrial Revolution was responsible: the drift to the factory-cities, with their restrictions upon the intake of the natural raw foods and dairy products. Rickets certainly is most prevalent in England. On the Continent, in fact, it is known as the English disease, having been first described by the English physician, Glisson.

But constitutional factors undoubtedly come into play in every nation and country. Diseases of the glands of internal secretion are more frequent in certain localities than in others. And it may be they which predispose to the development of conditions like rickets. The English seem predisposed to the development of rickets, and myxedema, deficiency of the thyroid gland. There may be a connexion.

Climate versus Diet

Racial characteristics, including those supposed to be as definite and fixed as those of the skeleton, have been modified in our time by changes in the dietary. This is an interesting result to put before those who claim everything for climate as a maker of race distinctions. As, for instance, Huntington (1915), who said that climate is the most important factor in determining the anatomical as well as the functional and psychological characteristics of peoples. He claimed that he had found a correlation between storminess of the cyclonic kind and the aggressive energy of a race. A mean temperature of sixty-four degrees Fahrenheit, a mean humidity of about 80 per cent, and a frequent but favourable range of temperature from day to night were most stimulating to activity. The combination of these three factors of climate produced the capacity for exploitation of natural resources, industry, and success, he asserted.

Now, it happens, as regards this problem, that a natural experiment has been carried out involving a whole nation. It makes diet out much more influential than climate, as

regards physique at any rate. McCollum and Simmonds have pointed out that climatically Japan deserves to rank as one of the most afflicted spots of the world. On the other hand, California is one of the least touched by variations in climate. Yet Japanese children born in America are larger, stronger, and healthier than their contemporaries born in the native country.

About twenty years ago, following an extensive immigration into California, Oregon, and Washington of Japanese males, the demand for females produced a great importation of 'picture brides'. The children born in the United States of these Japanese farmer fathers have been fed on dairy products and farm produce. This diet, so different from the fish and rice of the old country, has resulted in a change in what was considered an inherent and immutable racial characteristic, namely, stature. The children of these Japanese of the Pacific Coast States are two inches taller, on the average, than their parents and ancestors for generations back. And this has taken place under the most pleasant and fairly unvariable conditions of climate. Food, therefore, is proved to be a more important determiner of racial characteristics than climate.

A Prelude to All Revolutions

Revolutions come and revolutions go, but they never touch the root of most human misery. Have political revolutions meant more than the substitution of one tax collector for another? Or have they done anything more than substitute the assiduously subtle economic exploitation of populations for the grossly unjust? The economic interpretation of history is only a half-truth like the psychologies which would treat of man's mind or soul without reference to its connexions with his body.

According to the orthodox Marxian conceptions, it is the material conditions of life, the ways and means of producing sustenance and shelter, that determine the ideas and usages of social practices and institutions. These social effects make man a complex creation of culture rather than a simple animal creature. Basic changes in the methods of production of goods, as well as in their distribution and consumption, are reflected in fundamental modifications of peoples.

But can any such conception explain the persistence of

Animism, the doctrine of the distinctive separation of soul and body, under all sorts of economic and social systems on the face of our planet? Is it not possible to conceive of a majority of a population practising the superstitious rites of Animism, be they of Christianity, Judaism, or Mohammedanism, under the aegis of even the most utopian form of Communism?

No one, reflecting for a moment on the problem, can deny the enormous power for good and evil in a human life of ideas and beliefs. Such beliefs, conceived to be real but beyond immediate demonstration to the senses or the logic of common sense, may be more potent than the most obvious facts. How an Idea, wrapped in the suggestive awe of religion, manifests its potency may be realized by reviewing the sacrificial methods of the ancient religions, the techniques of the Spanish Inquisitions or the curious phenomena of the Salem Witch Trials. They were the offspring of certain definite theories concerning the relation of the body and the mind.

How much evil, misery, unhappiness, disease, and waste are still daily perpetrated as a consequence of the still widespread superstition that regards the body and the mind, the flesh and the spirit, as separate entities, with separate needs, characteristics, powers, and futures! In the private practice of a physician numerous examples of its malignant horrors continually present themselves. There are thousands of people who thus tear at themselves from within. There are thousands of others who are consumed both from within and without. So many suffer the tortures of the damned and finally break down under them. And all because they accept themselves as dual systems with different and antagonistic properties. For Animism proclaims us all to be double personalities leading a double life, the life of the body and the life of the mind or soul.

I, therefore, suggest the following as the simplest method for consummating what I believe to be the greatest practical revolution immediately possible in the intellectual world: the abolition of the body-mind separation in language. I propose that from the first day a child is subjected to any instruction from parent or teacher, the conjunction of body and mind as a single word be compulsory. Not body nor mind, but bodymind, should be taught.

Bodymind as a system should be the material of the child's first studies. It should be instructed in the elements of bodymind, as a prerequisite of all knowledge, simultaneously with its acquisition of the rudiments of reading and writing. It should be tutored, from the beginning of its educational life, in the language necessary to know its own personality. A whole series of other terms would be introduced into its vocabulary to avoid other unfortunate references to that ancient Animism, of which our language is full.

There are difficulties in this proposal. There is, first, the mental obstacle of seeing, as one, two abstractions apparently essential to everyday thinking. A similar difficulty exists in the case of the verbal separation of time and space, as well as matter and energy. But physicists and astronomers are gradually accustoming us to ideas of space-time and matter-energy. From the technical schools these usages are bound to spread through all the literate classes.

One of the obvious results of the adoption of bodymind as a familiar term, and a realization of its implications, would be a change in attitude of a great many people toward their food. Instead of seeing it as foreign matter to be ingested by the stomach or the blood, they would see it as something about to become part of themselves, that self they secretly cherish as 'I'. They would also see easily how the materials placed before them, simple or elegant, crudely or elaborately prepared, can influence every moment of their behaviour, moods, and morals; in short, life.

As Samuel Butler wrote in one of his Notes:

> All eating is a kind of proselytizing—a kind of dogmatizing—a maintaining that the eater's way of looking at things is better than the eatee's. We convert the food, or try to do so, to our own way of thinking, and, when it sticks to its own opinion and refuses to be converted, we say it disagrees with us. An animal that refused to let another eat it has the courage of its convictions and, if it gets eaten, dies a martyr to them. So we can only proselytize fresh meat, the convictions of putrid meat begin to be too strong for us.
>
> It is good for a man that he should not be thwarted—that he should have his own way as far, and with as little difficulty, as possible. Cooking is good because it makes matters easier by unsettling the meat's mind and preparing it for new ideas. All food must first be prepared for us by animals and plants, or we cannot assimilate it; and so thoughts are more easily assimilated that have been already digested by other minds. A man should

avoid converse with things that have been stunted or starved, and should not eat such meat as has been overdriven or underfed or afflicted with disease, nor should he touch fruit or vegetables that have not been well grown.

Sitting quiet after eating is akin to sitting still during service so as not to disturb the congregation. We are catechizing and converting our proselytes, and there should be no row. As we get older, we must digest more quietly still, our appetite is less, our gastric juices are no longer eloquent, they have lost that cogent fluency which carried away all that came in contact with it. They have become sluggish and unconciliatory. This is what happens to any man when he suffers from an attack of indigestion.

I have often said that there is not true love short of eating and consequent assimilation—the sperm and germ cells, or the two elements that go to form the new animal, whatever they should be called, eat one another up, and then the mother assimilates them more or less, through mutual inter-feeding and inter-breeding between her and them. But the curious point is that the more profound our love is the less we are conscious of it as love. True, a nurse tells her child that she would like to eat it, but this is a mode of, or rather the acme of, love—no nurse loves her child half well enough to want to really eat it: put to such a proof as this, the love of which she is so profoundly, as she imagines, sentient, proves to be but skin deep.

What, on the other hand, can awaken less consciousness of warm affection than an oyster? Who would press an oyster to his heart, or pat it and want to kiss it? Yet nothing short of its complete absorption into our own being can in the least satisfy us. The embrace must be consummate, not achieved by a mocking environment of draped and muffled arms that leaves no lasting trace on organization or consciousness, but by an enfolding within the bare and warm bosom of an open mouth—a grinding out of all differences of opinion by the sweet persuasion of the jaws, and the eloquence of a tongue that now convinces all the more powerfully because it is inarticulate and deals but with the one universal language of agglutination. Then we become made one with what we love—not heart to heart, but protoplasm to protoplasm, and this is far more to the purpose.

The proof of love, then, like that of any other pleasant pudding, is in the eating, and tested by this proof we see that consciousness of love, like all other consciousness, vanishes on becoming intense. While we are yet fully aware of it, we do not love as well as we think we do. When we really mean business and are hungry with affection, we do not know that we are in love, but simply go into the love-shop—for so any eating-house should be more fitly called—ask the price, pay our money down, and love till we can either love or pay no longer.

That is an immediate consequence of the modern chemical attitude toward human nature. When one makes love to food, one must be aware and beware of the consequences to the personality.

No story is more interesting than that of how we have arrived at this conception of the relation of the Love of Food to the powers and weaknesses of Bodymind.

CHAPTER I

BODYMIND AS A CHEMICAL BREW

TO appreciate how the bodymind is specifically affected by diet, it was necessary to possess an understanding of the chemical composition of foods. Also it was important to have the apparatus by means of which the fate of different food particles could be followed. In short, methods had to be evolved, by means of which could be recorded the history of the transformations foods undergo as they travel through the various organs and cells.

The process by which food is changed into life is called ' metabolism '. How metabolism influences character and temperament is our problem, since it is not the mere entry of food molecules into the stomach, intestines, and blood that is consequential, but what happens to them after they get there. No exploration of the chemical secrets of personality was possible until certain ideas about metabolism had developed historically. How these ideas actually grew in the minds of the men of genius who have made biochemistry, the chemistry of life, is a fascinating story.

It was necessary to create a picture of the bodymind as a sort of biochemical brew in order to understand, for example, how the personality was made more acid or more alkaline by the acids and alkalis latent in foods. This brew is a sort of multiple test-tube in which a number of chemical reactions are going on at the same time. Or, to put it more simply, it is a chemical apparatus. Now, a chemical apparatus, like a fire extinguisher, has both form and contents. The latter consist of chemicals which interact for whatever purpose the form has been conceived.

In the human being chemical contents and form are similarly

integrated. Form, the science of anatomy, was mastered before biochemistry, the science of the chemical contents and reactions of life, because it is easier to observe and dissect a dead body than to penetrate the secrets of the invisible molecules and electrons of the living.

To the biochemist of to-day, the individual presents himself as an extremely complex chemical system in a state of shifting equilibriums. The constituent chemicals of the system are continually interacting to produce all the miraculous manifestations of cells and tissues, organs and organisms, including the most marvellous of all, the human personality. The visible and invisible movements and forces which at once integrate and express the personality, varying all the way from a twinkling of an eyelash to the masterpieces of men like Beethoven and Einstein, are, from the biochemical point of view, the outward and concretely crystallized effects of chemical reactions.

It is the task of the biochemist to discover the precise nature of the interacting chemicals. Also, he must separate and isolate them in the purest condition possible. Then it becomes imperative to study their action when fed, or injected, or breathed into the organism. Only then can a true insight be obtained into the history, functions, and destiny of life and the human personality.

It is only in the last hundred and fifty years or so that the chemistry of the bodymind has been scientifically studied. Such practical biochemical operations as the fermentation of grapes to make wine, or the souring of apples and other fruit to make vinegar, the curdling of milk to make cheese, had been known for ages. But the science of biochemistry may be said to have begun with that great French genius, Antoine Laurent Lavoisier. Working with Pierre Simon La Place, Lavoisier fathered the modern quantitative approach to the problems of matter and energy in living things.

It was Lavoisier who proved that we breathe and burn oxygen. Also, that the oxygen is burned to form carbon dioxide. And that breathing consists in the inspiration of a quantity of oxygen-containing air and in the expiration of carbon dioxide. The two balance, while the nitrogen of the air remains unchanged. In his association with La Place, who was an astronomer, he proved also that breathing and burning are completely alike. Because oxygen is consumed

when any fire or flame burns, while carbon dioxide and water are produced, with the oxygen in the carbon dioxide and water exactly balancing the oxygen of the air that disappears.

As an honoured aristocrat, the humanity-worshipping terrorists of the French Revolution decapitated him. But no guillotine could destroy his contributions to the solid knowledge of mankind.

Lavoisier's Spiritual Ancestors

Lavoisier's work dealt essentially with that lightest of nothings, 'air', and its relation to human beings. It was the study of air, the all-surrounding medium in which all living things of the land swim, that created a true science of chemistry. Changes in ideas about the nature and function of air parallel curiously all the advances of early human knowledge concerning the universe.

At first it was regarded as an invisible nothing; then as an invisible something which was the substance of winds and storms. The Greeks first experimentally scrutinized and actively speculated about it. They distinguished between what they called the air, the lower thick envelope of the earth, and the ether, the upper lighter envelope. Alexandrian philosophers and naturalists founded the science of pneumatics, by their observations on the physical properties of air. They made the natural error of conceiving it a pure, elementary substance. In fact it was the symbol of purity to them. Anaximenes made it the primordial substance of which all other substances were compounded. And Aristotle, by making it one of the aboriginal elements, made that, like so many other false or unproved doctrines and dogmas, part of the unchallenged teaching of the scholastics down to the seventeenth century, a hundred years before Lavoisier.

Among the achievements of Galileo was that of proving that air was a material possessing weight. He weighed a copper ball containing compressed air and was able thus to compute the pressure of the atmosphere. In this, as in so many other modern fields, the intuitive genius of Leonardo da Vinci played its searchlight. According to Milne-Edwards, he wrote that no animal, whether of the land or sea or air, could live in an atmosphere in which a candle could not burn. Now this is a trite truism breathed in as obvious by every

school child. But it took three centuries of experiments, all by men of extraordinary ability, groping their way through the mazes of an invisible labyrinth (for such the atmosphere was to them), before that statement was accepted and understood as the truth it was.

A Mystic's Finding of Carbon Dioxide

Interestingly enough, the first constituent of the air discovered was carbon dioxide (carbonic acid gas). This component is most conspicuously contributed by the action of living things. The discoverer was van Helmont, of the Counts of Merode, ancient and noble blood of Belgium. He was a merged contradiction of mystic of the mind and the monastic scientist in the laboratory. He was a contemporary of Harvey, Galileo, and Bacon, the group who founded modern science. Educated at the great University of Louvain, he wandered restlessly from one science to another. Finally, taking his degree in medicine, he became a university nomad. He moved about from country to country, Switzerland, Italy, France, England. He was in Antwerp during the Great Plague of 1605. Four years later he married and settled down to the life of a practitioner. But he managed to spend all his spare time in his alchemist's laboratory.

He represented the transition between the follies of the old alchemy and the newly burgeoning scientific chemistry. Thus he believed that he was in possession of the philosopher's stone. And with a mere trace of it he had transmuted mercury into gold. As a physiologist, he became obsessed by a number of supernatural agencies he introduced as regulating, guiding, and co-ordinating principles in the body. He appropriated ideas like the archei from his forerunner Paracelsus. And he believed things like the following: That before the Fall of Man in the Garden of Eden, Archeus, or the intermediator between the Immortal Mind and Mortal Body, could act directly for the benefit of the person. But at the Fall there was introduced into the body the sensitive but mortal Soul, which became the shell of the Immortal Mind. Without the Soul, Immortal Mind cannot stay in Mortal Body. Death consists in the destruction of the Sensitive Soul and then Immortal Mind must leave Mortal Body to decay.

A brain dominated by such a confusion of biblical and

mystical ideas would not seem capable of the clear thinking and experimenting of natural science. Yet, he observed carefully the gas given off by burning charcoal and called it 'gaz sylvestre' (gas of the wood). Indeed, he coined the word 'gaz' or 'gas'. He showed that this gas was the same as the gas emitted when grapes ferment to make wine, or when vinegar is poured on chalk.

Also he found that gas was contained in the waters of Spa and might be given off from the earth in mines or caves, such as the Grotto del Carno near Naples. The cave was so named because it killed a dog, but not his master entering with it. For the gas, being heavier than air, stays near the ground and thus envelops the creature that cannot breathe above it. Therefore, also, this gas cannot support the life of animals or of a flame. To him belongs the eternal credit and fame of being the first to throw doubt upon the elementary nature of air and as the discoverer of one of its most important constituents. No substantial progress was made for a hundred years after his life.

John Mayow—Conjurer of Oxygen

Just about when van Helmont died, an Englishman was born who was destined to describe the existence of the other constituent of the air necessary for an understanding of the chemistry of metabolism; that is, oxygen. At Oxford he first obtained a degree in law, but entered the practice of medicine. He became a famous and fashionable physician of the summer resort, Bath. He, like van Helmont, carried on laboratory investigations at All Souls College, Oxford, in the intermittent respites from active practice. He died a year after the marriage, which, as he wrote, 'was not altogether to his content'.

In one of his classical experiments he showed that, if a burning candle and a small animal were both placed together under a bell-jar, both will go out sooner than either alone. From this definite fact he deduced that the air contained an element which he described as the nitro-aërial constituent, because it is also present in nitre. He surmised that breathing must be of that same nature, since 'animals, like fire, remove from air particles of the same nature'. He thus came very near to the solution of the whole problem of respiration. As often happens, his work was overlooked or forgotten because of the

general acceptance of a doctrine of the mechanics of burning then current. This doctrine involved a mythical substance called 'phlogiston' invented by the German chemist Stahl, physician to the King of Prussia.

These physician-chemists of the seventeenth and eighteenth centuries demonstrate how it was universally recognized at the time that chemistry and medicine were inextricably interlinked. The iatro-chemists, as they were called, were those who practised medicine as a branch of chemistry. In Paris, it is worth mentioning, there was Vieussens, who appears to have been the first physician on record to make chemical examinations of the blood regularly. He was also of those who prescribed large doses of the newly introduced drinks, coffee and tea, as treatments for acidity of the blood. Officially his methods were condemned by the Paris faculty as the 'upstart novelty of the century'.

Priestley and Scheele—Analysts of Oxygen

Oxygen, discovered by Mayow, was actually prepared by the English chemist Priestley, and independently by the Swedish chemist Scheele. Its history shows how slowly and painfully all the facts about oxygen were gradually made a part of human knowledge.

Priestley was not a chemist-physician, but a chemist-clergyman, a Nonconformist. He found time from his pulpit to work in the laboratory. His experiment began by using an atmosphere in which a candle had burned out and where no other candle could burn subsequently. He put a growing sprig of mint into that atmosphere. After several days he discovered that the atmosphere had changed, and another candle could now burn there. He then found that a similar flame-supporting gas could be evolved by heating the red oxide of mercury. Of course he never thought of it as an oxide, but regarded it as pure air. He found that mice could live in that gas indefinitely. Both the growing sprig of mint and the red oxide of mercury evolved oxygen.

Priestley was a radical and sympathetic to the American colonies in their struggle with the King. He published tracts opposed to the Tory government's attitude. On the fourteenth of July, 1791, the Constitutional Society of Birmingham celebrated the anniversary of the Fall of the Bastille. A lynching Loyalist mob gathered to destroy the 'enemies of

society'. They burned Priestley's chapel and sacked his house. He took refuge in London for a time, but finally followed his three sons who had emigrated to America. He ended his life as an American in Pennsylvania. His publications included six volumes of *Experiments and Observations on Different Kinds of Air.*

Scheele was a chemist-apothecary and obtained oxygen by analysing dioxide of manganese and other substances. He probably preceded Priestley in the discovery of oxygen by three years. But he succeeded further by distinguishing between spoiled air (nitrogen) and fire air (oxygen). He carried on a regular correspondence with Lavoisier, informing him of the details of his experiments and suggesting others for him to carry out. His only book was called *Air and Fire.*

Lavoisier the Magnificent

To complete the work of these solitaires of the laboratory, all of whom combined the pursuit of the chemistry of the atmosphere with some commercial profession, there now appeared a first-class man of genius, who completely revolutionized the field of human knowledge by synthesizing all the observations of his predecessors and adding many methods and ideas of his own. With him the scientific torch of investigation of the fundamental chemistry of the body passed into French hands from the English. These latter had first taken it over after it had been kindled in Italy by the creative ability of da Vinci and Sanctorius.

Lavoisier was of the seventh generation of a family which had raised itself socially with each generation. The family had begun in the sixteenth century with an Antoine who was a postboy in the royal stables. The father of the chemist was a rich man who gave his son the best available education of his time. The profession for which he was originally intended was the law. But the vivaciously intellectual atmosphere of Paris early turned his interests toward science. At the age of twenty-four, he was elected a member of the Academy of Science. Before that body he read a paper entitled 'On the Nature of Water and on Those Experiments which Pretend to Prove its Transformation into Earth'. This paper in its way was as important as that of Pasteur a hundred years later, in which was disproved the doctrine of the Spontaneous Generation of Living Matter.

Lavoisier took rainwater, supposedly pure, and boiled it in a flask for one hundred and one days. Mineral water was deposited in the flask, but the whole, weighed on a balance, remained unchanged in weight. This test was made as exact and sensitive as could be obtained at the time by the official gold-weigher of the monarchy. But the flask itself lost in weight. It was thus demonstrated that the earthly matter into which water for two thousand years had been supposed capable of transmuting itself was derived from the glass of the flask. The experiment was crucial in a number of ways ; not the least of which was the introduction of the method of weighing pure substances, the method which is the heart of modern scientific chemistry.

Lavoisier then applied the new method of accurate weighing to facts communicated to him in correspondence by Priestley and Scheele. He took the red calz of mercury, heated it and found that an air was evolved ' eminently respirable '. Oxygen was produced, air in which a sparrow could live and a flame could burn. He found also that the weight of this ' respirable air ' or oxygen equalled exactly the loss in weight of the heated mercury compound. If, however, carbon was mixed with the red mercury calz and then heated, not the ' air eminently respirable ' (previously described by Mayow, Priestley, and Scheele) was generated, but ' fixed air ' or *carbonic acid gas* (previously described by van Helmont and Black). The name of ' fixed air ' was coined by Black, an Englishman, because it combines with or becomes ' fixed ' by limewater.

The decrease in weight of the red mercury calz could be accounted for by the weight of the newly formed ' fixed air '. It equalled the weight of the original carbon plus the weight lost by the mercury compound. Thus, for the first time in the history of the subject, Lavoisier showed the chemical relation of oxygen and carbon in carbon dioxide as a compound of carbon and oxygen.

Next, inspired by the principle, as he enunciated it, that ' life is a chemical function ', he turned his attention to the application of his new discoveries to the central problem of life. This is the problem of the *means by which life maintains itself as life*, from minute to minute and from hour to hour.

There was the old analogy of life being like a flame. It was in the year after the publication of the American Declaration of Independence that he elucidated the nature of fire. While

all the world was seething with the news of the political revolution in the New World, Lavoisier made his statement as the result of his experimental work. He said that when it keeps alive by breathing air, an animal burned and consumed definite quantities per hour of the air 'eminently respirable' or 'oxygen' (as he called it) and produced in return an equivalent quantity of 'fixed air' or carbon dioxide. He called the latter 'aeriform calcic acid'.

Three years afterwards, working with the astronomer La Place, he actually founded the modern study of metabolism by measuring the amount of heat given off by a guinea-pig in ten hours. They found the quantity of heat produced by measuring how much ice in the same chamber melted during that period of time. By also measuring the amount of carbon dioxide absorbed by limewater during the same period, it was possible to measure for the first time what is now known as the 'respiratory quotient'; that is, the relation of the amount of oxygen burned to the amount of carbon dioxide generated, and the heat equivalent of both. This is a method and a principle now used in everyday medicine in the determination of the *basal* metabolism or what the bodymind burns when at rest. It is its overhead of energy expenditure.

In 1789, the year of the Fall of the Bastille, just when another Revolution, the French Revolution, was beginning, Lavoisier published the results of similar experiments carried out on a human being. His subject and also his collaborator was Seguin, the chemist who had invented 'a simple, easy, and rapid method of gas analysis'.

It shows the type of imagination working in Lavoisier's mind, which is the quality that divides first-rate from second-rate minds in science, as well as in art. For he at once saw the law of the conservation of energy—that energy can never be destroyed, but only transformed from one state into another. He was able to write:

This kind of observation [of the heat produced by an animal or a human being during a given period of time] suggests a comparison of forces concerning which no other data exist. One can learn, for example, how many pounds of weight-lifting correspond to the effort of one who reads aloud or of a musician who plays a musical instrument. One might even value, in mechanistic terms, the work of a philosopher who thinks, the man of letters who writes, the musician who composes. These factors, which have been

considered purely moral, have something of the physical and the material which this work allows us to compare with the activities of a man who labours with his hands. It is not without justice that the French language has united under the common expression ' work ', the effort of the mind with that of the body, the work at the desk with the work at the shop.

Thus far we have considered respiration only as a consumption of air. The same kind for the rich as for the poor, for air belongs equally to all, and costs nothing. The labourer who works enjoys indeed in great measure this gift of nature. Experiment has taught us that respiration is a true process of combustion which every instant consumes a portion of the individual. This combustion is greater when the circulation and respiration are accelerated and is augmented in proportion to the activity of the individual life. A host of moral considerations suggest themselves from these determinations of physical science.

What fatality ordains that a poor man, who works with his arms and who is forced to employ for his subsistence all the power given him by Nature, consumes more of himself than does the idler, while the latter has less need of repair ? Why the shocking contrast of a rich man enjoying in abundance that which is not physically necessary for him and which is apparently destined for the labouring man ? Let us take care, however, not to calumniate Nature and accuse her of faults undoubtedly a part of our social institutions and perhaps inseparable from them. Let us be content to bless the philosophy and humanity which unite to promote wise institutions which tend to bring about equality of fortune, to increase the price of labour, to assure to it just recompense, to offer to all classes of society and especially to the poor more pleasures and greater happiness. Let us trust, however, that the enthusiasm and exaggeration which so readily seize men united in large assemblies, that the human passions which sway the multitude, often against their own interest, and sweep the sage and the philosopher like other men into their whirlpool, do not reverse an outlook with such beautiful vistas and do not destroy the hope of the country. . . .

We end this memoir with a consoling reflection. To merit well of humanity and to pay tribute to one's country, it is not necessary to take part in the brilliant public functions that have to do with the organization and regeneration of empires. The naturalist may also perform patriotic functions in the silence of his laboratory and at his desk ; he can hope through his labours to diminish the mass of ills which afflict the human race or to increase its happiness and pleasure ; and should he, by some new methods which he has opened up, prolong the average life of men by years or even days, he can also aspire to the title of benefactor of humanity.

But Lavoisier was not only the contemporary of Priestley and Benjamin Franklin. He was also the contemporary of Robespierre and Marat, who was his enemy. For while he had been quietly inaugurating the Chemical Revolution, they were uproariously conducting the French Revolution. Marat, who was destined to be killed in his bath, not only dabbled with political doctrines, but also committed himself on problems of physics and chemistry. He had opined that a flame put in a closed chamber was extinguished because the heat of the flame suddenly expanded the air, so that the flame was blown out by the air's movement.

Lavoisier had proved the precise nature of the phenomenon, which completely contradicted Marat's ideas. Marat, in his paper, *L'Ami du Peuple,* published an attack on Lavoisier under the heading 'Modern Charlatans', as follows: 'Lavoisier, the putative father of all the discoveries that are noised about, having no ideas of his own, snatches at those of others, but having no ability to appreciate them, he quickly abandons them and changes his theories as he does his shows.'

But Marat went further than newspaper attacks. Lavoisier was active in public life as a tax-collector, a *fermier-général,* who guaranteed the collection of revenues for a percentage. He became a tax-collector in order to obtain money for his researches.

He applied the same scientific spirit to his work here also. In superintending the manufacture of gunpowder, a chemical proceeding, he devised ways and means of improving the quality and output of it. He carried out experiments in scientific farming and animal breeding which he communicated to the peasants of his district. Thus he anticipated the agricultural experiment stations of modern states. But his public services were ignored, indeed held against him by the Jacobins, who had abolished the Academy of Sciences on the ground that the Republic had no need of savants. A few months later, in 1794, when he was about fifty years old and at the height of his powers, he was guillotined in the Place de la République. The man was a true martyr of Science, since it was his method of getting financial support for his work that led to his death.

Liebig—The Genius of Vision

The next great name in the history of metabolism and the development of modern knowledge of diet and nutrition is that

of Justus von Liebig. He was born during the Napoleonic Era at the beginning of the nineteenth century. His father had a dye warehouse and was interested in experimenting with the dyes he dealt in. He hoped to produce natural dyes by artificial methods. For these experiments he fitted a laboratory and his son assisted him there from his earliest days. There they carried out experiments in chemistry as described in the books which the Royal Library of Darmstadt permitted to be lent to the inhabitants of the town. Gradually he developed such a passion for these books that he not only became indifferent to every other interest of children, but also to other school studies. So, like Darwin, he was stigmatized a dunce by his teachers.

Nevertheless, he persevered and was particularly encouraged by the Court Librarian, Hess, who was also a botanist. Thus the two moulding influences in the boy's life were his father and the librarian. He read books, as Edison is said to have done, not according to any course of learning, but on the system of total demolition. He began with the first volume of the top shelf, and ingested their contents one after the other. Thus he consumed the thirty volumes of Maquer's *Chemical Dictionary*, Basil Valentine's *Triumphal Car of Antimony*, Stahl's *Phlogistic Chemistry*, the works of Cavendish, Priestley, Mayow, and Lavoisier. And this does not account for the thousands of essays in the bound volumes of chemical periodicals.

This promiscuous but voluminous reading produced in him, as he afterwards wrote, the habit of thinking in terms of phenomena. This custom, of *visualizing phenomena*, he likened to the seeing of the painter or the auditory imagery of the musician who think in terms of tone which must be mathematically related as phenomena are logically related. ' There is in the chemist a form of thought by which all ideas become visible to the mind as the strains of an imagined piece of music,' he said in his autobiography.

That is why he lauded Faraday, a contemporary physicist, likening him to an artist of genius. To him who looks for sharp demarcations of human activities, the artist and the scientist are supposed to be as far apart as the sun and the earth. But it is just as possible and necessary to be an artist in biochemistry as to be a mathematician in architecture or an anatomist in sculpture.

As the means of his father's laboratory were limited, Liebig performed the same experiment time and time again until, as it were, he had learned it by heart as well as by hand. So he could imagine the most minute details of resemblance and difference in the various results he obtained. In addition, he kept his eyes open everywhere for ideas to duplicate in the laboratory. At a neighbouring soapmaker's, he watched the boiling of fats and learned how white soap was made. He proceeded to make a piece of his own and perfume it with turpentine. Whenever chemicals were used, whether metals as at the smith's and the brassfounder's, or liquids in the house of the tanner and dyer, he was present, lending a hand and returning home post-haste to imitate what he had seen done.

And even in the great market-place, the centre of the town, he learned by watching pedlars. One demonstrated how to make fulminating silver and showed the red fumes of the devil, generated when he added nitric acid to his silver. Also, he made a perfect cleaning fluid out of this silver liquid, by adding a fluid which smelt like brandy. With this the dirty collars of the people were purified in public free, gratis, and for nothing, to prove the validity of everything else on the counter.

An adventurous eye-minded boy like this was no fit pabulum for digestion of the ordinary schoolmaster. As he himself said, he could retain nothing of what was poured in by the ear. One day the venerable rector of the academy questioned him in public, and remonstrated with him in his superior scholastic way. The master wound up by asking the usual rhetorical question, 'What do you think will become of you?' Liebig answered that he expected to become a chemist. The old man, in fact the whole school, cascaded into uproarious laughter because of the absurdity of chemistry as a profession. This, mind you, was just a hundred years ago!

What could be done with such a boy? To what practical commercial uses could his unfortunate natural proclivity be put? Make a druggist out of him! So he was apprenticed to an apothecary in the neighbouring town of Heppenheim. But at the end of ten months, he had learned everything that he could of the apparatus and the chemicals in the place. And besides, he was always making a nuisance of himself,

performing those everlasting experiments. So the druggist sent him home.

He was sixteen now and, after persistently nagging his father, he was sent to the newly established University of Bonn. Actually he was to study the official science of chemistry as it was to be expounded by the famous Professor of Chemistry, Kastner. But Kastner's teaching was vitiated by the old medieval method of lecturing abstractly, as follows: 'The influence of the rain upon the moon is clear, for as soon as the moon is visible the rain ceases.' There was no attempt to apply common sense to reason, as that perhaps the moon was visible because the clouds hiding it had been dispelled as rain, and so on.

No experimental demonstrations or laboratory work were done. Kastner's chair was regarded a startling innovation in university teaching. For, although there was a quickening of the intellectual life in Germany after Waterloo, and many universities were being founded, there had never been a chair devoted solely to chemistry. It was generally expounded together with toxicology, pharmacy, materia medica, and practical medicine by the professor of medicine. One suspects justification for the medical satires of Molière, when such could be the state of affairs in an enlightened country a hundred years after his death.

Nevertheless, Kastner was supposed to know more about chemistry than anyone in the country and Liebig followed him faithfully when he moved from Bonn to Erlangen. But at Erlangen, Liebig finally found out Kastner. The master had promised to analyse some minerals with him, but it turned out that he had no more notion how to do it than Liebig himself. So the student returned home to Darmstadt again.

Since there were no chemical laboratories in any German university at that time, Liebig organized at Bonn and Erlangen small groups of students in a physio-chemical club. Each member had to read a paper on some topic on physics or chemistry. Generally these were taken from articles appearing in the most important periodical of natural science of the day, Gilbert and Schweiger's *Journal*. It thus corresponded to the seminar which is now part of the advanced courses in science given in most universities of the world to-day. Since there was no work for him to do in chemistry, he made up

for his lack of interest in other subjects in his primary school days by studying them now, particularly languages. So he prepared himself for Paris.

And it was there in the autumn of 1822 that his genius was finally recognized. The death of Lavoisier had not been the death of French chemical science. There was, in Paris, a whole group of men of the greatest talent who carried on the spirit of Lavoisier, men like Wohler who came from Sweden where he had worked with Berzelius.

Now Liebig was just twenty when he addressed himself to Thénard, then President of the Academy of Sciences of Paris. He asked permission to present a report of his analysis of fulminating silver. It was that same substance with which the street fakir had so powerfully affected his curiosity and imagination in his childhood.

Liebig was permitted to read his report. It was a momentous occasion and he was flustered. As he finished packing the materials used in his demonstration, one of the audience inquired what his future investigations and studies were to be. He was most inquisitive and graciously invited Liebig to dinner the following Sunday. The chemist accepted, but was so embarrassed he neglected to ask the name and address of his host. Sunday arrived and Liebig almost perished of chagrin, not being able to keep the appointment. The next day a friend remonstrated : 'What on earth did you mean by not coming to dine with Alexander von Humboldt yesterday, when he had invited Gay-Lussac and other chemists to meet you ? ' 'I was thunderstruck,' said Liebig, and he rushed off as fast as he could to von Humboldt's lodgings and made the best explanation he could. The famous geographer and traveller was appeased by the explanation and told him that, unfortunate as the oversight had been, since several members of the Academy of Science had been expressly invited to meet him, he would see to it that they would be there the following Sunday evening. There he was introduced to Gay-Lussac, the most eminent chemist of the time. The latter was so impressed with the young enthusiastic genius that he at once invited him to work in his private laboratory in the Arsenal. They planned to continue together Liebig's researches on fulminating silver.

It was through the influence of von Humboldt and Gay-Lussac that a year later, when he was barely twenty-one,

an extraordinary professorship of chemistry was conferred upon him at the University of Giessen. This was in his native land. He had left as a peripatetic dunce and returned an acclaimed conqueror of his chosen field. There he built the first well-equipped chemical laboratory for the teaching of analytical chemistry and the methods of chemical research. Students streamed to it from all over the world, many of whom became famous later. He managed to infuse into his lectures the French charm as well as accuracy and lucidity of exposition, which touched the emotions as well as the intellect of his hearers.

Liebig devoted himself to originating and improving methods of organic analysis of plants and animals and their secretions. About twenty of his most talented students, gathered from every country of Europe, worked directly under him on the problems, carrying out yearly thousands of experiments. They worked from daybreak until midnight. The laboratory assistant constantly complained that he could not get the workers out in order to clean up.

After sixteen years of such activity, Liebig published the results. The underlying principles were involved in his *Chemistry Applied to Agriculture and Physiology*, which passed through nine editions. Two years later his *Animal Chemistry* came out. Another book, *Chemical Letters*, was generally received as a popular work, but was never intended to be, either in form or substance. All were pioneer publications containing facts and principles which have since become the groundwork of their respective sciences.

It is Liebig's great distinction that he was the first to classify foods as proteins, fats, carbohydrates, and salts. Proteins, he declared, replaced tissue destroyed in the body, while fat and carbohydrate provided energy. To many original contributions to the store of concrete facts, measurements, and observations, in the field of the science of the chemistry of life, he added the remarkable synthetic power of his mind, which is the characteristic of great genius. And so with Lavoisier he deserves eternal credit for establishing the modern biochemical viewpoint in medicine.

Liebig's work is best summarized in an extract of a letter written by Carl Voit, one of his famous pupils. It emphasizes something not properly appreciated to-day—the importance of the *synthetic* attitude and its achievements in science,

without being derogatory to the *analytical* attitude. He is the first-rate scientist who creates principles and those laws of nature which are mankind's most precious intellectual possessions. It is the second-rate collector, the myopic observer peering only at isolated facts, who fails to realize their universal significance. To generalize is the great contribution of the human mind to the universe.

Voit wrote:

All these chemical discoveries, to which Liebig so largely contributed, gave him his fruitful conceptions concerning the processes in the animal body. Before him, the observations were like single building stones without interrelation, and it required a mind like his to bring them into ordered relation. To appreciate this, one has only to read physiological papers written before the publication of his books in order to witness how his writings changed the mental attitude toward the processes in the organism. The chemical discoveries on which he based his conclusions were, in fact, matters of general knowledge, but it was he who applied them to the processes of living things. Scientific progress is determined by the establishment of correct interpretations and the creation thereby of new pathways and problems. A schoolboy has a better knowledge of many things than the wisest man had formerly; and he laughs at the ignorance of his forefathers because he does not understand the history of the human mind.

The man of science ought to realize the factors which have given him the advantage he holds. But there are textbooks on physiology in which the chapters on the animal mechanism do not even mention the name of Liebig. This anomaly is possible only for those who do not understand history, and who hold only the new to be worthy of consideration. Liebig was the first to establish the importance of chemical transformations in the body. He stated that the phenomena of motion and activity which we call life arise from the interaction between metabolism and activity and that not only heat but all movement was derived from metabolism. He investigated the chemical processes of life and followed them step by step to their excretion products.

In 1852, when he was forty-nine, Liebig was called to Munich as the professor of chemistry in its renowned university. Ever since it has been one of the most illustrious world centres of biochemical research. In the court circles of the Mad Ludwig he gave popular lectures on his researches. As the other great lion and genius of the town, he shared with Richard Wagner the worship of the crowd. Liebig's Extracts, Liebig's Gluten Bread, and Liebig's Infant Food made him

famous among the lower classes as well as the upper. It is reported that when his gluten bread was first made by the bakeries, people stood in long lines to buy the new scientific loaves. It was the beginning of the worship of scientific technique by the German people. Liebig lived another score of years or so, but his creative period was over.

Lavoisier proved the relation of air, oxygen, and carbon dioxide to metabolism. Liebig showed that the chemical essentials of food were the organic carbon containing chemicals, proteins, the fats, now being called lipins, and the sugars and starches, now known collectively as carbohydrates, as well as mineral salts. All over the world, in their wake there has been an enormous, ever more and more ramifying, development of biochemistry.

At the time Liebig returned to his homeland to establish the first biochemical laboratories, another pioneer biochemical laboratory was founded in what was then St. Petersburg, now Leningrad. A Russian, Lemonessoc, was its head. He had also studied under the French masters. But Liebig's laboratory remained paramount.

Many Americans went to study under Liebig in Munich. When they returned to their country, they in turn created laboratories of their own. These laboratories of biochemistry have grown and multiplied, until now a biochemical department is the commonplace adjunct of every medical school, hospital, and medical institution. To William J. Gies belongs the credit of opening the first in America for undergraduate medical students in America at the College of Physicians and Surgeons in New York.

Measurement of Energy in the Bodymind

After Lavoisier's death, the French Academy offered a prize for researches extending the work of Lavoisier in the measurement of heat energy metabolism. The names of two competitors, Deprez and Dulong, have come down to us. They improved Lavoisier's method by putting their small animals in a chamber surrounded by water. Then, by measuring the rise of temperature of the water, there was obtained a direct record of the amount of heat produced in a given time. They also weighed the amount of carbon dioxide *ex*pired as well as the water *per*spired. Their work was an important stride along the road of progress.

In 1849, Regnault, a French physicist, devised an apparatus in which small animals could be kept breathing a measured quantity of oxygen which was steadily replenished. He could thus determine exactly how much oxygen was burned in an hour. He found that small animals consumed more oxygen and produced more carbon dioxide in proportion to their size than larger ones. Sparrows, for instance, absorbed ten times as much oxygen in an hour as chickens. Silkworms and beetles used about a litre per kilogram of body weight, while frogs and earthworms used only about one tenth of a litre.

A year later (1850), their work was extended and confirmed by two Germans, Bidder and Schmidt, connected with the University of Dorpat. They established the fundamental principle that *for every species of animals there is a typical minimum metabolism.* Nowadays this typical minimum of energy production for any individual is called the 'basal metabolism'. It is measured under *basal* conditions, after a night's sleep and after no food has been taken for at least twelve hours. They wrote: 'It [the typical minimal metabolism] is just as constant [in any species] and characteristic, as the anatomical structure and the corresponding mechanical arrangement of the body.'

In 1860, Carl Voit, professor of physiology at the University of Munich (where Liebig was professor of chemistry), attempted to persuade one of his co-workers to make a respiration apparatus large enough for a good-sized dog. A physicist, Pettenkofer, who was in the employ of the city of Munich as the chief of its health laboratory, went ahead and produced an apparatus large enough for a human being. It consisted of an airtight chamber into which pure air could be pumped from the outside and samples of breathed air removed periodically by suction. An analysis of them could then be made for oxygen, carbon dioxide, and water. This apparatus made Munich the centre of research in metabolism. And it became a Mecca of all serious students of the subject.

Among these were two, Rubner, a German, and Atwater, an American, destined to make classic contributions to the subject. Rubner measured the heat values of foods burned directly in an apparatus called the 'bomb calorimeter'. He showed that in burning fat and starch the body produced as much heat as when they burned outside the body. But when protein was burned in the body, less heat was produced

than when it was burned outside. Later, when professor of physiology at the University of Marburg, he proved the validity of the law of conservation of energy for all animals studied. Energy is neither created nor destroyed in the bodymind. That meant that metabolism represents an exact balance between the intake of energy and material and the outgo. Yet they may and do enter and leave in entirely different forms. The energy that enters is chemical energy, stored in the food particles. It is transformed by metabolism, and leaves the body as energy of heat, energy of motion, and energy of electricity.

According to these laws, the carbon of starch, fat, and protein leaves the body as an exactly equivalent amount of carbon dioxide, but only when these foods are completely burned. In 1902, Rubner published a book on *The Laws of the Consumption of Energy in Nutrition*, a classic in its field. During the Great War of 1914–18 his counsels concerning food were ignored by the orthodox in Germany. His predictions concerning the dire results of disregarding his advice came true. Diseases of nutrition and their consequences became almost epidemic in his country.

Atwater, the First American Student of Metabolism

W. O. Atwater was the most distinguished and original of Voit's pupils. When he was made professor of chemistry at Wesleyan University in Connecticut, he associated himself with Rosa, a physicist. Together they developed a method for the measurement of metabolism in human beings. The apparatus used the principle first employed by Regnault. They measured the rise in temperature of a water apparatus that absorbed the heat produced by the human being.

The Atwater-Rosa calorimeter, as it was called, was a most complicated machine. For a time, it was available only in a few places: in the United States Department of Agriculture at Washington, the Russell Sage Institute of Pathology, and the Carnegie Institute in Boston. A pupil of Atwater's, F. G. Benedict, collaborating with him since the beginning of the present century, worked out a number of improvements and simplifications which have now made a universal use of it possible. To-day it is almost as easy to make a metabolism reading in a physician's office as it is to take the blood pressure.

By means of these instruments it became possible to show conclusively that the amount of heat given off by an individual at rest (under standard conditions) was equal to the amount of heat energy that was calculated theoretically when a given amount of oxygen was burned with the food to produce carbon dioxide outside of the body. The theoretical calculation was verified by the actual burning of combustible food materials in what is called a ' bomb calorimeter '. There was a direct relation between the amount of oxygen consumed and the amount of heat produced. It therefore became apparent that, if one could measure the amount of oxygen consumed in a given amount of time, one could state the amount of heat energy evolved during that period of breathing or living. This, the principle of indirect calorimetry, is the one employed in the metabolism apparatus in daily use in physicians' offices.

Zuntz, head of the Agricultural College of Berlin, used this principle to construct a portable respiration calorimeter that a man could wear like a knapsack while walking. So he recorded the amount of energy he produced and consumed under different conditions. For instance, when he was walking at sea level, or walking against gravity, as in mountain climbing.

One of his students, Magnus Levy, applied this apparatus in the study of sick individuals. He found that in the disease of the thyroid gland called exophthalmic goitre, there was a great increase in the production of heat. Sometimes this increase amounted to as much as one hundred per cent. Basing his efforts upon these results, Benedict was able to construct a portable metabolism machine. By means of this it is possible anywhere to-day to make an accurate measurement of the rate at which the bodymind is producing calories of energy. The determination may be done, under the right conditions, in about a quarter of an hour.

The fundamental fact behind the machine is the law that oxygen respired is at once consumed. There is no device anywhere in the organism for the storage of oxygen, as there is for the storage of fats, sugars, minerals, and proteins. The amount of oxygen consumed is the amount of oxygen that is burned, when an average food mixture is undergoing combustion.

This possibility should truly be regarded as one of the

marvels of modern medicine. Instead of having to shut the subject up in an airtight chamber, with all sorts of devices necessary to prevent leaks and errors, he now lies comfortably on a table and breathes oxygen through a tube connected with a closely fitting mouthpiece of rubber. Breathing of air through the nose in the interim is prevented. The carbon dioxide expired by the patient is delivered into a soda lime container which absorbs it. As the volume of oxygen is consumed, a pen on a revolving drum provides a graphic picture of how the patient is breathing, as well as a permanent record of how much oxygen he has burned.

Thus, after about a hundred years of intensive serious work in the precise determination of energy metabolism, it became possible to measure it in human beings, quickly and accurately. Now studies are being made in their own countries of the metabolism of Chinese, Negroes, Hindus, and Indians. It has been found that Oriental peoples have a lower metabolism than the Occidental peoples. Similarly, it has been observed that the Oriental peoples tend to have a lower blood pressure.

The Ingredients of the Life Brew

As a result of these biochemical studies, the conclusion is justified that the individual is essentially a complex functioning chemical system. He is a complicated vat of chemical substances in which a huge brew is being constantly consummated. Many ingredients are parts of the concoctions. These parts are reacting continually and continuously in a manner comparable to the mechanical meshing of the gears of an automobile. The different chemicals interact. They interlock in an exquisitely specific fashion. In the course of the chemical interaction, energy is produced and tissues function. Thus a muscle contracts, a gland secretes, a nerve area thinks.

Nothing is, therefore, of greater concern to mankind than a searching study of these chemical parts: the different chemicals found in the human bodymind. A few hundred biological chemists have been doing it for a hundred years. They have looked for, separated and isolated in as pure a condition as possible, the chemical constituents of protoplasm. And these are the constituents of personality. They have observed the effect of deprivation or excess of one or another

of them upon the health and functioning of the bodymind. Hopkins has estimated that about a thousand chemical entities have so far been coaxed out of the tissues of living things. But thousands are needed as workers in the field. It is interesting with what a few principles this tremendous detailed knowledge of the chemical constituents of personality has been obtained. What is done is the following:

1. A crude extract of the tissues, organs, or cells suspected to contain a particular chemical substance is obtained. As soon as possible a liquid solution of it is desired, because it can thus be most easily manipulated.

2. It is purified by the removal of contaminating substances.

3. An attempt is made to obtain it in crystalline form so as to make certain of 100 per cent purity by crystallization and recrystallization.

4. The substance is fed or otherwise introduced into the bodymind in limited or excessive quantities and the result studied.

5. The effects of removal of the same substances from the diet are observed.

6. By studying the blood and the different fluids of the bodymind, an attempt is made to understand just how the food chemical is changed in its travels through the cells and tissues, and how it ultimately leaves.

Take, for example, melanin, the pigment of the skin which is increased in amount by the action of sunlight, and is normally very concentrated in the skin of the negro. First, a crude mash extract is made of the skin. This contains the pigment and various interfering substances, such as salt. The interfering substances are removed by means of various reagents which combine with them and take them out of solution. The melanin is finally thus obtained in a purified concentrated solution from which it can be separated in crystalline form or as a pure powder. This can then be fed or injected and the effects of such feeding or injection studied. In this way detailed knowledge of the history and function of each substance is obtained.

It is by these methods and principles that a real fund of information has been accumulated concerning the origin, history, and destiny of the molecules of food that enter the mouth. How it passes from the stomach into the blood to be distributed to the various places where it is needed has

been studied. And finally how they are ejected, changed or unchanged, through the skin, the lungs, the intestines, or the kidneys.

Not all the thousand-odd substances of the bodymind so far obtained are present in food. A number of them are manufactured out of food elements. The food chemicals are specially necessary for its creative chemical reactions. Diet supplies the raw materials for the chemical factories, the glands of internal secretion. These, too—as, for example, theelin, the product of the ovary, or adrenalin, manufactured by the adrenal glands—are investigated by similar methods.

Can we Learn about Living Personality from Dead Protoplasm?

It should always be remembered that in the majority of his operations the biochemist deals, not with the living substance, but with the dead materials resulting when life ceases. For in order to study and analyse the constituents of living things he cannot somehow inspect and select what he wants as he would, say, in walking through a building. Rather must he wreck the building and destroy much in order to make an inventory of its contents. Consequently he is always aware of the danger of confusing artifacts generated by his methods with the true chemistry of the cells. And undoubtedly at times he has been fooled into supposing himself upon the track of some new chemical constituent of protoplasm, when, as a matter of fact, he has created a new substance in the test-tube, out of the others really present in the tissues. By the manipulations of his methods, a something was made which never existed within the living cells.

But awareness of this confusing possibility has stimulated the chemist of life to refine his weapons. He has learned to make his approach as delicate and as subtle as possible. He uses a number of checks and controls which he has invented. Thereby he has justified his conclusions concerning the presence and function of whatever substance about which he happens to be talking. If he is a wrecker, he needs must be scientific and work toward his end with all the rigours of the scientific method. Thus he has achieved a mental reconstruction of living matter out of the dead wreckage he has analysed. More and more he becomes less and less like a small boy who smashes the watch in order to learn what

makes it go. Now he resembles rather the jeweller who can separate it into its parts, change or replace them, and restore a perfectly functioning mechanism at the end.

A Tale of a Thousand and One Chemicals

As a specialist in nutrition, the biochemist should make the human race conscious of the importance of the ingredients of food. Nothing is more important than to make people aware of the determining influence of the thousand and one chemicals they ingest upon their personality.

These necessities of nourishment are compounds of only about a fifth of the known chemical elements, the irreducible simples of ordinary chemistry. There are about twenty elements that are involved in the metabolism of living matter. Their presence in adequate amounts is the prerequisite for health and health-producing diets. They include hydrogen, oxygen, carbon, nitrogen, sodium, potassium, calcium, magnesium, sulphur and phosphorus, iodine, chlorine, fluorine, iron, silicon, copper, manganese, and zinc.

None of these exist in the bodymind in the simple elementary form, but as compounds of various degrees of complexity. The simplest of them is water: there is enough water in the average human weighing about one hundred and fifty pounds to fill a fifteen-gallon barrel. The carbon compounds are the most numerous: there is enough to fill with charcoal a box two feet by one and a half by one and a half. The other elements in their combinations are present in much smaller proportions. The least of these mineral compounds are infinitely important for normal proportions. The effect of their absence is being intensely studied in plants and animals.

In plants the results are most grossly obvious, but are entirely analogous to the abnormal effects observed in animals. Thus it has been shown that the two elements which are absolute essentials for the completion of growth are nitrogen and calcium. Plants deprived of them become stunted. Nitrogen is necessary for the making of the crude material of cells. Calcium is required to hold them together. Potassium is the power which changes seed into flower, by progressive development. If it is deficient, the plant stops its evolution at some intermediate stage. If no or insufficient magnesium is given the plant, curious errors and anomalies of growth result. And if no iron is supplied, a pale colourless creation

evolves, lacking the richly pigmented tints of the normal growth. Other inorganic chemicals, such as copper, manganese, zinc, probably play an important part in nutrition.

To Enliven the Brew: the Vitamins

The nineteenth century distinguished itself by its concentration upon the gross matter of nutrition—calories, proteins, fats, and carbohydrates. Through Lavoisier, Liebig, Voit, Atwater, Zuntz, and Benedict, it erected upon a solid foundation the larger calculations of dietetics. But it happened that the discovery of the 'little' but indispensable contributions to nutrition made by the vitamins (present in fresh foods in the most minute doses) revolutionized fundamentally the science of dietetics in the first three decades of the twentieth century. It is interesting that similarly, the physics and chemistry of the *fin-de-siècle,* seemingly finally established, were completely overturned by the discovery of tiny quantities of powerful radium.

Not that it had not been long suspected that certain specific food principles were a necessity of health. As all scientific notions can be traced back to some first attempt at clear thinking on the problem by Aristotle, so can medical ideas be tracked to Hippocrates, his Greek contemporary, who wrote on Air, Water, and Places, five hundred years before Christ. Hippocrates taught that all food contained a unique principle, the 'aliment', which was what really supplied nourishment. 'Aliment' probably corresponded to our conception of 'protoplasm'. He was correct in that the chemical composition of all food corresponds to that of protoplasm, since all food was once living matter.

As pointed out by McCollum and Simmonds, the theory of 'aliment' was orthodox doctrine as recently as 1833. In that year the American Army Surgeon, Beaumont, carried out classical observations on digestion in the stomach, exposed by a gunshot wound, of the Indian, Alexis St. Martin. As he avidly watched the progress of digestion through the hole in the abdomen of his patient, he never doubted that it was a most simple process he was observing. He accepted the view that, while there were innumerable foods there was only one 'aliment' present in all of them. And this was extractable.

It was his contemporary, the Frenchman, Magendie, who

must be credited with realizing the importance of experimental analysis of diets to determine their adequacy and the function of their different ingredients. He was the first to experiment and compare different foods like sugar, olive oil, butter, and so on. He was the distinguished pioneer in emphasizing the indispensability of the nitrogenous compounds in foods. They were designated 'proteins' by his contemporary, Mulden.

The condition first recognized as due to a deficiency, a lack of something essential in the diet, was the ancient disease called 'scurvy'. Hippocrates knew about scurvy, because he described cases in the Greek armies of men who suffered from pains in the legs and were prostrated. Also, their gums became gangrenous and their teeth fell out.

Armies forced to subsist on limited and monotonous rations have always exhibited epidemics of scurvy during war-times. De Joinville, who was physician to Saint Louis and his Crusaders when they invaded Egypt during the thirteenth century, described an epidemic of it. He noted the blue, spongy, bleeding gums and the complete loss of endurance and vitality by its victims.

It was, however, in the British Navy that scurvy was first demonstrated to be due to a lack of fresh raw food. The long voyages of exploration of the British navigators of the sixteenth, seventeenth, and eighteenth centuries, stimulated by the discovery of the New World, provided plenty of opportunity for the development of scurvy among the sailors susceptible to the diet forced upon them. This diet consisted of salted animal food and 'hardtack'. For many months they ate little or no fresh vegetables or plants. Scurvy was epidemic among them.

As far back as 1720, a Dr. Kramer wrote in his book on Military Medicine that neither medicine nor surgery cured scurvy:

> But if you can get green vegetables; if you can prepare a sufficient quantity of fresh antiscorbutic juices, if you have oranges, lemons, citrons, or their pulp and juice preserved with whey in cask, so that you can make a lemonade, or rather give to the quantity of 3 or 4 ounces of their juice in whey, you will, without other assistance, cure this dreadful evil.

Then Lind, as surgeon of the *Salisbury*, carried out definite controlled experiments upon his sailors sick of scurvy. At

one time, he was treating twelve of them, without enough oranges and lemons for all. To all of them he gave the best nursing care possible. To two of them he gave oranges and lemons, the others he gave cider, while to still others he gave the recommended medical treatment of the times, such as cream of tartar and elixir of vitriol. Those treated with oranges and lemons were quickly cured, while those who were given cider showed some recovery. But those given the traditional medicines became worse. In 1757, Lind published his experiences and views, emphasizing that lemon juice could be carried on long voyages to prevent scurvy, but that it was useless to depend upon dried vegetables, such as spinach. The latter, he said, was deprived of ' something contained in the natural juices of the plant which no moisture whatever could replace '.

Through the strenuous efforts of Lind, who emphasized the value of lemons, oranges, sour cabbage, and all fresh fruits and vegetables, lime juice was introduced as part of the everyday diet of the enlisted men on shipboard in 1795, and made compulsory in the Royal Navy in 1804. The Lind diet practically made the disease non-existent in the Royal Navy, the thousands of cases reported every year until that time being completely prevented.

Lind's ideas were partly derived from those proposed and triumphantly applied by the famous explorer, Captain James Cook. For three years he sailed the seas of the Southern Pacific with only a single case of scurvy among his 118 men —an unheard-of achievement—because he fed his men sweetwort and sauerkraut liberally. But it was not until 1865 that regulations concerning the feeding of fresh food and fruit juices were made compulsory by the British Board of Trade for all the ships of its merchant marine.

Hess has pointed out that in 1841, Budd wrote that the scurvy preventing action of certain fresh foods was due ' to an essential element, which, it is hardly too sanguine to state, will be discovered by organic chemistry, or the experiments of physiologists, in a not far distant future '. Nearly a hundred years had to elapse before that prophecy became a reality.

It was another naval physician, this time a Dutchman named Christian Eykman, who in 1896 started the ball rolling in the direction of the discovery and experimental study of

the different vitamins. He was not interested in scurvy, but in another disease of sailors called beri-beri. Common as scurvy was among European sailors and Occidentals in general, its frequency was outdone by the occurrence of beri-beri in the East.

Beri-beri is a form of neuritis resulting in paralysis. It was prevalent among Orientals and Eastern sailors in particular. There were certain native physicians who believed that its origin was a matter of diet and treated it accordingly. But nothing definite was known.

While scurvy is strikingly a disease of the bones and joints, beri-beri is primarily a disease of the nerves. Scurvy attacks the metabolism of the skeleton while beri-beri hits the chemistry of the long nerves that supply the muscles of the extremities. Consequently, pain and disability are the outstanding symptoms of scurvy, swelling and paralysis the presenting phenomena of beri-beri.

These differences of two dietetic diseases illustrate a fundamental principle: that not all organs are equivalent as regards their needs for the different food substances. Each organ and each tissue has its own specific chemistry. To maintain its normal condition, one organ or tissue may require much more of a specific substance than another. The organ or tissue which becomes diseased with the slightest deficiency of a given food substance is the one that has the greatest need for it. In the case of Vitamin C which cures scurvy, it is the bones that are most dependent upon it. In the case of Vitamin B, which cures beri-beri, it is the nerves which are most sensitive to a lack of it.

Beri-beri was epidemic in the Japanese Navy in 1884. The Japanese Admiral Takaki decided to test the idea that it might be due to the diet of the sailors which consisted largely of rice, and food rich in starch and poor in protein. One training ship with 276 men on board was given the usual rice diet on a nine-months' cruise. On this trip 169 men came down with beri-beri and 25 died. A second training ship with about the same number in the crew was then sent over the same route. Its diet, though, was different. The rice was reduced and replaced by meat and milk. For the ten months of that voyage only fourteen cases of the disease were reported. And the astounding part of it was that all of the fourteen men had refused the new diet. These experi-

ments of Takaki were taken to prove his original guess, namely, that beri-beri might be a disease of protein deficiency. For apparently he had replaced a high starch diet by a high protein diet.

But about twelve years later, Dr. Eykman, stationed at the Dutch settlement at Java, made a curious observation. It was an observation that had nothing to do directly with his work in his hospital. An epidemic of paralysis among fowl to whom were thrown the unused cooked rice on the daily menu of the institution attracted his attention. The quick clinical eye of Eykman recognized the similarity of the symptoms presented by the diseased fowl to those of beri-beri.

Deliberately, then, he experimented and found that a beri-beri neuritis could be regularly induced in birds by a diet of polished rice, and could be prevented or cured by unmilled rice or rice polishings. He concluded that the disease was caused by the absence of something present in the unmilled or unpolished rice (brown rice), but absent from the white or polished rice. Also that this something was restorable by the addition to white rice of the discarded brown rice polishings.

This something that cured beri-beri was the first vitamin to be definitely described and experimentally demonstrated —the vitamin afterwards to be known as Vitamin B, or the anti-beri-beri vitamin. For this first demonstration of a vitamin disease, although he himself was unaware of vitamins, Eykman was awarded the Nobel Prize more than thirty years after his experiments were published.

About five years later, Rohman published the results of an interesting investigation. He showed that if mice were fed, instead of natural foods, a mixture of artificially purified foods, such as potato starch, wheat starch, oleomargarine, egg albumin, vitellin and casein, and the proper salts, no living young could be obtained from them. This proved that unknown substances were present in natural foods, necessary for the rearing of offspring. He was upon the trail of the vitamins before the word was even coined. In the same year another Dutchman, Pekelharin, reported a piece of work, in which he stated the vitamin idea so clearly that the quotation deserves to become classic:

When white mice are fed on bread baked with casein, albumin, rice-flour, lard and a mixture of all the salts which ought to be

found in their food, while they are only given water to drink, the animals starve to death. During the first few days all is well. The bread is eagerly nibbled and the mice look healthy. But soon they get thinner, their appetite diminishes and in four weeks all the animals are dead. If, however, instead of water they are given milk to drink, they keep in good health, though the quantity of albumin, lactose and fat which they assimilate with the milk is quite negligible in comparison with what the bread on which they are fed contains. The element in the milk which keeps the animals alive also occurs in the whey from which casein and fat have been eliminated. Till now my efforts, constantly repeated during the last few years, to separate this substance from the whey and get to know more about it, have not led to a satisfactory result, so I shall not say any more about them. My intention is only to point out that there is a still unknown substance in milk, which, even in very small quantities, is of paramount importance to nutrition. If this substance is absent, the organism loses the power properly to assimilate the well-known principal parts of food, the appetite is lost and with apparent abundance the animals die of want. Undoubtedly this substance not only occurs in milk but in all sorts of foodstuffs, both of vegetable and animal origin.

In 1906, now a generation ago, Professor (now Sir Frederick) Gowland Hopkins likewise demonstrated that milk contained an unknown substance necessary for growth and health, without which health was lost and growth ceased. It was Hopkins who first stated clearly as a general principle that there must be something essential to the life in natural foods not present in artificial foods. Concerning this substance in milk and other unknown substances, effective in very small quantities, but essential for normality, he expressed his convictions in no uncertain terms as follows:

No animal can live on a mixture of pure protein, fat and carbohydrate, and even when necessary inorganic material is carefully supplied, the animal still cannot flourish. The animal is adjusted to live either on plant tissues or the tissues of other animals, and these contain countless substances other than proteins, carbohydrates and fats. . . . In diseases such as rickets, and particularly in scurvy, we have had for long years knowledge of a dietetic factor, but though we know how to benefit these conditions empirically, the real errors in the diet are to this day quite obscure. . . . Scurvy and rickets are conditions so severe that they force themselves on our attention; but many other nutritive errors affect the health of individuals to a degree most important

to themselves, and some of them depend upon unsuspected dietetic factors.

In 1913, a Polish chemist, Funk, reviewed the work done by contemporaneous workers on these mysterious midgets of nutrition. After detailing his own chemical work on them, he suggested that they all be called ' vitamines '. Later the word changed to ' vitamins ' to suggest their vital importance for life and the healthy functioning of all the organs of the bodymind. Although there was some objection to the word at first, it has now been generally adopted.

In 1916, McCollum, one of the first and most active of the American investigators, proposed that the first letters of the alphabet be used to distinguish the vitamin found in milk and necessary for growth, the ' fat-soluble A ', from the other, found in unmilled cereals and other fresh foods, preventing beri-beri, the ' water-soluble B '. Since then Vitamin C has been accepted as the designation for the anti-scurvy vitamin, Vitamin D for the vitamin preventing rickets, Vitamin E for the one essential for sexual fertility, and Vitamin G for the one preventing pellagra. Vitamin G is also known as the P–P, or pellagra-preventing vitamin.

Goldberger, working in the United States Public Health Service, was most strenuous in tracking down Vitamin G. He began his work in 1914, collaborating with Waring and Willets, also of the United States Public Health Service. Pellagra is a disease which has long been a widespread scourge of the South. It is a disease with a predilection for warm climates, like those of Spain and Italy, Roumania and Egypt. It was not generally diagnosed in the Southern States of the American Union until 1908. But between 1908 and 1917, 170,000 cases of it were reported.

Pellagra is a disease of the skin and mucous membranes primarily, and of the nervous system secondarily. The mouth becomes sore and inflamed, and then the hands, feet, and other symmetrical parts of the skin. The spinal cord shows signs of being diseased and finally the brain. Insanity or death ensue.

Italian investigators favoured the idea that the disease was caused by the eating of mouldy maize. As long ago as 1845, Roussel claimed that it could be cured by a milk diet. And in 1856, the Italians Lussana and Frua stated

that by a proper diet they had cut the death rate in about eight thousand cases from about 24 per cent to about 4 per cent, and had raised their percentage of cures to 70 per cent, whereas under other methods it was 20 per cent.

In spite of all this, it was still a moot question in 1914, when Goldberger began working, whether pellagra was an infection or a diet disease. Goldberger observed that in insane asylums where those with pellagra were confined, neither physicians nor nurses were attacked by the disease. He therefore concluded that it was not an infectious disease due to a germ transmitted by contact. In the institutions where the food was supposed to be alike for patients and their attendants, he found that the latter were favoured with the milk, meat, and fresh vegetables when there was not enough to go round, as there generally was not. He then compared the diets of those who developed pellagra with those who lived in the same districts but remained immune. Those without pellagra were eating eggs, milk, and fresh meat, while those who had the disease did not, especially during the winter.

In 1914 and 1915, he made experimental observations in an insane asylum and two orphanages and finally on a prison farm. They provided eggs, milk, fresh meat, and fresh vegetables in the diet. In one of the orphanages, 67 pellagrins were cured and remained cured. At the other, 105 were cured, without any signs of recurrence. Among 99 of the insane asylum who were cured, not one relapsed after the institution of the new diet.

In 1915 his famous prison-farm experiment was begun. Pardons were provided for healthy white volunteers in the State Prison who were willing to become experimental test subjects. Eleven men who offered themselves were selected. It was planned to put them upon the kind of foods used by the cotton-mill workers of the South among whom pellagra was epidemic. White males were made the subjects because they were less susceptible to the disease. The experiment was started in the spring because ordinarily it is worse in the winter. In other words, conditions were made as difficult as possible for the reproduction of the disease.

On the prison farm the experiment was started and lasted from April 19, 1915, and continued until October 31 of that year. There were 180 convicts on the farm in April and 30

remained until October. Of those on a regular mixed diet not a single one developed pellagra, although it was prevalent in the neighbourhood. The eleven experimental subjects were put on a diet of artificial cereal products, molasses, and pork fat, with less than 4 per cent derived from cabbage, collards, turnip greens, and sweet potatoes, which the others received. After five and a half months, six of the eleven convicts on the limited diet presented the characteristic skin lesions of pellagra, as diagnosed by a number of physicians familiar with the disease.

Thus he proved that pellagra, a disease leading to insanity, was due to the absence of an important something present in fresh foods. The disease of the experimental convicts was cured when they were given the fresh foods.

In 1920, Voegtlin and Harries reported finding evidence of pellagra in infants nursed by pellagrous mothers. Lustbert and Birchett in 1922 stated that such pellagrous infants could be cured if they were no longer fed the mother's milk, but were given cow's milk, fruit juices, and vegetable purées. In 1917, Chittenden and Underhill put dogs on a diet of bolted wheat flour, peas and cotton-seed oil, and produced a condition much like that of human pellagra. The animals' mouths became inflamed, there was diarrhoea, and the skin presented an appearance suggestive of pellagra.

The experimental pellagra-like disease of these dogs became known as ' black tongue ' disease. It was found that it could be cured by yeast, which also contains Vitamin B, the vitamin which cures beri-beri. It became evident that Vitamin B really consisted of two different substances, since two different diseases were cured by it. It was then discovered that the two could be distinguished by means of the effect of heat upon the yeast. Under the proper conditions the Vitamin B which cured beri-beri was destroyed by heat, while the vitamin which cured pellagra remained. To the latter the name Vitamin G was given. Goldberger, who was the first to insist upon the dual nature of what was called Vitamin B, had been calling it the P–P, or pellagra-preventing factor. It is a substance essentially lacking in corn meal, white flour, rice, and cotton-seed oil, which contributed largely to the diet of the Southern population who developed the disease. Pellagra is now prevented among these people by teaching them to eat the right foods.

The story of the identification of the vitamins is a series of romances worthy of a separate book.

But enough has been told of the heroic saga which stretches from Lavoisier to Goldberger, both of whom died at and because of their work, to provide some conception of how few and how great were these figures who peered into the great cauldron of the life-brew. It is now in order to outline the actual essentials of all diets, which is based upon the work of all these investigators.

CHAPTER II

THE CHASSIS OF ALL DIETS

NOW, no matter what observations are to be made on the relation of food to character, it must be constantly borne in mind that all diets have certain elements in common. For it has been shown conclusively by animal experiments that a bodymind, to grow and thrive, requires at least a minimum of certain chemical essentials present in what it eats and drinks. These food essentials might be called the chassis of all diets, since they constitute the basic frame along the lines of which specific individual diets can be constructed.

The composition of a diet must be made to conform to the composition of the individual. And as no two individuals are absolutely alike as regards their chemical composition, no two individuals should be given diets or put themselves upon foods that are absolutely alike. It becomes necessary, in dealing with the problem of nutrition of any man, woman, or child, to obtain first some insight into what they are made of, and what they are capable of making out of their food.

Individual composition means the individual chemical make-up. In other words, we should like to know something of what a man has done with the materials he has put into himself in the past, before deciding what he is to put into himself in the present and in the future. Once this is realized, people will keep as careful records of what they have fed their children during the first few years of life as they now do of their heights, weights, and general behaviour. A ‘ dietetic conscience ’ will develop among them. In time adolescents and adults will also be affected by it.

We are not in a position as yet to attain a *complete* chemical analysis of the living individual. But a complete chemical analysis, the ideal desideratum, is by no means a prerequisite condition for our problem. Methods are available by which

the *chemical-type characteristics* of the bodymind may be revealed. The chemistry of the blood, after a night's rest and without breakfast, may be determined with a great deal of accuracy. This provides clues to the basic chemical reactions of his cells, their defects and their excesses. And then a study may be made of what happens to the blood chemistry, of how it changes and reacts, after he takes food, whether it be a mixed meal, or much of a particular food like meat or milk. By modern apparatus such determinations may be made quickly and accurately.

Individual chemical composition expresses *individual constitution*. Indeed, an individual's constitution may be defined as his *chemical materials and their relations*. So by taking into consideration the present composition of an individual in planning and studying his diet, and its effects upon his behaviour and character, the most respectful attention is being paid to the demands of his individual constitution.

A rising chorus of emphasis upon individual constitution is the distinction of the outstanding researches in medicine to-day. Louder and louder grow the voices in reaction to the passing enthusiasm for bacteria as the secrets to the causes of the diseases and decay of Man. In the last two decades of the nineteenth century, there was a great rush for the gold mines of bacteriology. Microbes were hunted with microscope and culture tube. The ideal behind the intensive hunt was to find the germ and kill it with a serum. Thus the Utopia of health and the complete prevention of disease was to be attained.

Then the first two decades of the twentieth century witnessed the elaboration of the amazing potencies of the glands of internal secretion. It became apparent how differently human beings were equipped with them. This led to a revival of interest in the doctrine of human constitution. To-day every one is talking ' constitution ': constitutional weaknesses and predispositions and the struggle against the internal destiny which is a man's inherited make-up.

Even in disease, the realization has come that it is of paramount importance to understand the materials a man is made of at birth and their after-history in reaction to the environment. Since, in so far as they determine his resistance, they might be even more important than the microbes.

The materials a man starts out with are the materials of

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heredity, present in the reproductive cells, known as the chromosomes and their constituent genes. They in turn manufacture the endocrine glands and the subtle hormones they secrete. Concomitantly with the interest in these, there has evolved those recent fruitful researches on the materials a man daily puts into himself—his food. And it is these together which have made the modern study of man a branch of the science of chemistry, with solid foundations so different from the empirical simplicities of twenty years ago.

The Three Sets of Chemicals that Make Character

Genes, chromosomes, endocrines, hormones, foods—all are materials, chemicals interacting and reacting to make the individual what he is. From the moment he is born to the moment he passes from the scene to eternal dissolution, they interact. As regards these, all human beings have something in common. All men are equal in that they have the same number of chromosomes and about the same number of genes. There is a democracy, too, about the glands of internal secretion, since all men possess similar endocrine glands producing the same internal secretions. Also they all eat about the same foods—proteins, sugars, fats, minerals, and vitamins.

But what are most striking and most intriguing as regards all these materials are not the similarities, but the *differences*, between men and women, boys and girls. These differences are traceable to differences in *quantity* and *quality* of these chemicals.

At the genesis of men and women in the womb of their mother, the genes and chromosomes are given to them as their capital in life. The endocrine glands make the most or the worst of that capital. And the foods are added to that capital, acting to create debits or credits, with all kinds of after-effects.

Of these three chemical makers of personality—chromosomes, hormones, and nutrients—only two, the endocrine glands with their products, and the foods of a diet with their constituents, are directly susceptible to chemical analysis. An exact quantitative study can be made of their relation to the functions of the bodymind in general, and to the requirements of a special individual in particular. Thereby may be tested, not only the view that one man's meat, but also one man's fruit, vegetables, cereals, salads, may be an-

other man's poisons. When that significant law of the science of nutrition is generally recognized and applied, the greatest advance possible in individual health by natural methods will be achieved. It will, however, turn out to be another way of paying respect to individuality. It will be the outcome of modern concentration upon the nature and peculiarities of each unique human constitution.

Similarities in Diets

Yet all diets are alike and must be so as regards their general construction. In other words, they are the same as far as qualitative analysis is concerned. They must all contain (1) water, (2) the twenty amino acids of proteins, (3) the glucose of sugars and starches, (4) the fatty acids of fats, simple or phosphorized (lecithans), (5) the solid alcohols of which cholesterol and ergosterol are the types, (6) the twelve minerals (sodium, potassium, calcium, magnesium, iron, manganese, copper, chlorine, iodine, fluorine, phosphorus, and sulphur), (7) the different vitamins, and (8) oxygen. That is the octave of nutrition.

Essentially human bodies have the same qualitative chemical composition as the foods that enter them. But there may be the sharpest difference in the quantitative chemical composition of any two individuals. This is reflected in the mirror of the chemistry of the tissue, the blood, and the urine.

The diets of the two individuals must vary likewise. *For the fundamental principle of any diet must be the quantity of the different food essentials to be allotted to any particular individual,* in relation to *his ability to use or metabolize them.* That will depend upon the requirements of his constitution and the capacity of his endocrine glands. In short, the quantitative chemistry of his diet should correspond to the quantitative chemistry of the individual.

This means that human beings cannot simply be treated as animals. No human dietitian can resort to the methods of the modern scientific farmer in the raising of his prize livestock. Such a farmer knows precisely how many pounds of meat can be evolved from the grain he feeds his cattle. With his exact calculations he rations his milch cows to yield the maximum of high-fat milk. Of course, he does not have to bother with nervous disposition and glandular constitution, although the man who feeds race-horses or prize dogs must.

But the human dietitian needs always to emphasize individual differences and to consider them seriously in prescribing a diet. That is why, for example, it is wrong to teach that the panacea for the malnutrition affecting 50 per cent of children is a quart of milk a day and green vegetables. For an enormous number of children *cannot adequately handle more than a pint or half a pint of milk a day, and many not even that.*

The Heat Value of a Diet

The heat value of a diet should be the first to be considered, since fuelling is the primary function of food. Its fuel performance consists in its capacity to supply heat when burned. Thus it maintains the body at its normal temperature and provides a source of energy for the dynamics of its engines and activities. The unit measuring the heat value of a food, the calorie, is a concept taken over from physics. It is the amount of energy in terms of which the heat value of any food may be stated.

This heat requirement of a diet may be spoken of as its ' calorigenic power '. The calorigenic requirement of any diet is its capacity to generate heat as measured in terms of calories. It is the *primary* requirement of any diet.

The glucose of the sugars and starches, collectively known as the carbohydrates, the fatty acids and the glycerine of fats, and the amino-acids of proteins can be used as fuel for heat by the cells of the body because they are incompletely oxidized chemical compounds. Though they contain a certain amount of oxygen, they can combine with more oxygen to the point of saturation. This combination with oxygen is combustion. For it is the addition of oxygen that in the organism constitutes the slow burning known as oxidation.

The output of water and carbon dioxide (the end products of such combinations of sugars and fats with oxygen) can be used to measure the rate at which the body has been burning. This, the heat metabolism, is naturally different before and after eating. Also, calculations may be made which show how much heat has been produced out of fat, how much out of sugar and starch, and how much out of protein.

Standards have been worked out which rate the average heat-producing values of foods. Upon these may be based

diets containing the average amounts of foods necessary daily as far as calories are concerned. One gramme of fat has a fuel value of about nine calories; one gramme of protein about four calories; one gramme of sugar (carbohydrates in any form) also about four calories. At complete rest, a little over a thousand calories or two hundred and fifty grammes of carbohydrate would suffice for replacement purposes. For a few hours out of bed, about fifteen hundred calories are needed. Above that the amount of heat necessary for activity can be graded according to occupation or special pursuit. The labourer needs most, the clerk the least.

Especially must the caloric requirement of children be carefully filled. Otherwise, they will not grow properly, no matter how correct the diet is in all other respects.

Children under one year of age need 600 to 1,000 calories
Children from one to two years need 1,200 to 1,400
Children from two to five years need 1,400 to 1,600
Children from five to ten years need 1,600 to 2,000
Children over ten years old need 2,000 to 2,600

Among children the injurious effects of insufficient calories are encountered more frequently than those of excessive calories. But among many adults it is much more often an excess of calories that is injurious. It may either stimulate the metabolism too much, so that we see the spectacle of the person who the more he eats the thinner he gets. Or the excess calories strain the metabolism, and obesity with its train of degenerate diseases follows. For practical purposes the number of calories of any food can be computed in terms of hundred-calorie portions. Lists of these can be obtained and translated into terms of quantities conveniently servable at table. A margin of safety, of at least 10 per cent, should be provided.

The Sugar Requirement

So much for the basic heat requirement of any diet. It must be satisfied first because the fundamental prerequisite of the self-maintaining metabolism of such a dynamic system as living matter is *energy*. We do not know what energy is in the sense of reducing it to something staple and familiar. But we can and do define it as the *power to do work*. And living matter is constantly working to keep alive.

The law of the conservation of energy, that energy can only come out of pre-existing energy in an exact way, has been shown to apply equally to all living, as well as non-living, things. Now this energy that goes out as heat or work must first come into the bodymind as the energy of light, heat, electricity, but, most importantly, as the chemical energy of food. Therefore, the first concern of any diet must be to provide a sufficiency of energy-evolving foods.

For several thousands of years, man has discovered and exploited the fact that the chemical element most useful to evolve energy is carbon. When he made his first fires burning wood, he was utilizing the carbon of cellulose or wood fibre, in which it is combined with hydrogen and oxygen. And when he used coal (simply the fossilized corpse of the dried cellulose of ancient plants) to make roaring fires that could revolve steam engines, he was consuming the carbon in almost a pure form. It should not be surprising, then, that living matter has for millions of years been doing the same thing. It burns the carbon of carbon-containing foods to supply itself with energy.

For man and the animals, incapable of synthesizing carbon compounds as plants can, two forms of carbon-containing foods are available. First come the sugars and their parents, the starches. They can burn quickly and thus provide energy speedily. Secondly, there is fat. It burns more slowly and therefore is used when energy is not needed in a hurry, or when much sugar has been burned, and the body wishes to keep as much as possible of its energy in reserve.

Now, the sugar with which the body works is not the familiar table variety, which is cane sugar. It is rather the fruit sugar, which for a long time was somewhat despised in the fruit markets as 'glucose'. The popularity of cane sugar is due to its sweetness. It may be prepared by extraction and purification from the natural sources. Plants manufacture it—that is, sugar beet, maple sugar or syrup, and several of the fruits. It is also known as 'sucrose' or 'saccharose'.

Not nearly so sweet is the sugar of milk discovered by the old Romans, technically designated as 'lactose'. It occurs in the sheaths of the nerves as well as in milk. And then there is 'maltose', or the sugar of malt, appearing in large quantities in beer. It is present in malt because of the

breaking-down of the barley grain during germination, changing the starch into maltose.

This breaking-down of starch in the germination of barley is typical. It illustrates the relation of the starches to the sugars in general. Starches are synthesized by plants from carbon dioxide and water in the presence of ultra-violet light or sunlight. They are stored as reserve food material for the reproductive cells of the plants: the seeds which germinate in the spring under the influence of increased warmth and moisture. Man, being an exploiting predatory parasite, consumes these reproductive cells with their starches. They are conspicuous in cereals, such as wheat, which he calls the staff of life. In his mouth and his intestines, the starch is digested or broken down to form maltose. First it goes through an intermediate form of carbohydrate known as the 'dextrins', which are easily soluble in water.

But all sugars, cane, milk, malt, molasses, or syrups are ultimately broken down to form the sugar of the blood, which is a glucose. These sugars and their precursors, the starches, are more complex than glucose because it is when they are split, by acids or by enzymes, that the blood sugar is formed. Thus cane sugar splits into glucose and fructose. The latter is entitled to the designation of fruit sugar. In the liver it changes into glucose by way of glycogen, the starch of the organ. Milk sugar when split becomes glucose and galactose, another simple sugar which the liver can turn into glucose.

The female breast or mammary gland has the power to turn glucose back again into galactose. When galactose is combined with glucose, which also occurs in the female breast, lactose, or sugar of milk, is formed for the nourishment of the suckling. It is present in all milks. But maltose has the ability to split directly into glucose, giving two parts of glucose from one of maltose. So starch, including the animal starch of the liver and muscles, known as 'glycogen', goes through several stages before it yields glucose. First, it forms a series of quasi-sugars called 'dextrins', then maltose out of the dextrins, finally glucose out of the maltose.

Glucose, then, is the great carbonaceous material burned by the body as its source of energy. That is why the amount of glucose in the blood must be maintained at least at a certain minimum level. For it must supply energy of effort as well as the energy of resting metabolism. From the stand-

point of energy, all the twenty-five hundred calories needed by the average moving individual could be obtained from food containing 100 per cent of glucose. These would be glucose-containing materials such as: cane sugar, beet sugar, milk sugar, malt sugar, dextrin, or starches. But there would be a number of objections to such a diet which will now be considered.

So it is apparent that diet, in order to produce calories effectively, must contain enough sugar or sugar-forming material. To be able to generate heat, a diet must supply glucose. Therefore, this is the second of the basic requirements of any diet, the first being its heat content.

The Fat Balance

Now the required amount of the *quickly* burning carbonaceous food, glucose, will also be determined by the concomitantly consumed quantity of fat. Fat is the *slowly* burning carbonaceous constituent of food. Now, as it has been put metaphorically but effectively, fat burns in the fire of the sugar. The flames of the burning glucose complete the combustion of the basic fatty acid, which is diacetic acid. Diacetic acid stands in the same position to the fats that glucose bears to the carbohydrates.

If there is not enough glucose in the blood to keep the home fires sweetly burning, the fats smoke and smudge the flame. That causes their partly broken-down acid products to escape into the blood. Seeping into the reserve alkalinity of the blood, their acidity generates an acidosis which first dulls and stupefies and ultimately throws the individual into a coma.

To prevent this fatty acid type of acidosis and the consequent fatigability and coma, it is necessary to provide at least two parts of glucose to one part of fatty acid. Therefore, if a diet contains (and the average does) about 30 per cent of fat, about 60 per cent should consist of sugar or starch.

These fatty acids causing acidosis are called the 'ketonic acids'. The process of their formation is named 'ketogenesis'. And the burning of glucose to counteract ketogenesis is naturally known as 'anti-ketogenesis'. The ratio of glucogenic (anti-ketogenic) food to ketogenic food is said to be a two to one ratio: the ketogenic-anti-ketogenic ratio.

But the fats have other dietetic virtues besides acting as

slowly burning sources of carbonaceous material. The unsaturated fatty acids are those which burn slowest of all. Besides serving as vitamin carriers, they have been shown to be absolutely necessary to physical and mental health. That function will be dealt with later.

Fats are either animal or plant in origin, while glucose is characteristically plant-derived. Vegetable fats are generally liquid (oils), while animal fats are more or less solid (mutton or suet fat, pigs' fat or lard, wool fat or lanolin). Fats generally used are compounds of glycerine and the high-carbon fatty acids, such as the stearic acid of suet, the palmitic acid of palm oil, the oleic acid of olive oil, and the butyric acid of butter.

Most fats contain combinations of the stearic, palmitic, and oleic acids. The more solid the fat, the more stearic acid it contains, the more liquid the more oleic acid. These fats are known as the stearins, the palmitins, and the oleins.

By a process of hydrogen addition (hydrogenation) of fats and oils, their hardness may be controlled to suit the taste of the consumer. The fats are heated above the boiling point of water and hydrogen is introduced by means of some catalyst, like finely divided platinum. In the reaction, the unsaturated oleic acid takes up hydrogen and becomes the more saturated stearic acid. One should be on guard against these hydrogenated fats, as the heating destroys the flavour and the important vitamins. To make sure of the natural oils, olives and nuts or their pure oils should be eaten. The cotton-seed oil (often masquerading as olive oil), peanut oil, and corn oil on the market should be regarded with suspicion unless specifically guaranteed against hydrogenation. Butter and cream are the least adulterable of the fats, and easily obtainable. Fats must be in a diet in order to provide the *fatty acid* requirement of a diet.

The Protein Quota

Proteins are the most essential constituents of living matter or protoplasm. Consequently, whenever we eat something that once was alive (as we do always), a certain amount of protein is bound to be present.

Proteins occur in foods like cheese, white of egg, and lean meat. They are extremely complex compounds of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulphur. White

of egg itself contains several proteins, one of which, egg albumin, was one of the first studied and has recently been obtained in crystalline form, which will make possible studies of its chemical constitution looking toward its artificial synthesis.

Upon analysis, proteins are found to be constituted of about twenty nitrogen-containing acids known as the ' amino-acids '. The amino-acids are essential building stones for the construction of new living matter. They are the heart of protoplasm.

Discovery of the importance of a complete and balanced amino-acid intake has been one of the great achievements of modern biochemistry. It explains why one cannot live upon a single protein alone, but must have a variety of proteins. For different proteins have different amino-acids.

Proteins may be classified by their content of the different known amino-acids. This is known as their ' biological adequacy '. Most of the proteins contain a number of these amino-acids, but very few have all of them.

Under the stress of the absence of certain amino-acids from the diet, the cells of the body may synthesize many of them. But four, tyrosine and tryptophane, histidine and cysteine, cannot be synthesized. Without enough of them in the food, the organism degenerates and falls into illness leading to death. They are called the ' essential amino-acids '.

The protein requirement of an average individual has been stated to be one and a half calories per pound of weight. For a man weighing 150 pounds, this means that 225 calories or 56 grammes of protein are necessary. There are some who would put it at 30 to 40 grammes for every one. Others would make it 75 to 125 grammes. As we shall see, the protein requirement varies markedly with individuality. Too much protein may be consumed as well as too little. Each extreme may cause physical and mental disturbance, affecting the chemistry of the bodymind in the most remarkable ways.

Although it is now generally accepted that a diet should contain as much of the various essential amino-acids as possible, it may be that for certain individuals an excess of tryptophane, tyrosine, cysteine, or histidine may be harmful. Also, certain amino-acids may be necessary in excess, to balance other needs and capacities of his metabolism. Thus individuals having pernicious anaemia, or a tendency to

anaemia, should have an excess of the pyrrole ring containing amino-acids, proline, and oxyproline.

Some of the principal proteins grouped according to their solubilities are:

The albumins of eggs, milk, fruits, vegetables are water soluble.
The globulins of meats, nuts, etc., are salt-water soluble.
The glutenins of cereals are alcohol soluble.
The nucleoproteins—in the germs of seeds and glandular organs like liver, thymus, pancreas, etc.
The phosphoproteins—such as the casein of milk and cheese.
The acid and alkali soluble proteins—such as occur in ligaments, tendons, and bones.

But this is not a complete classification.

The proteins satisfy the amino-acid requirements of a diet.

The Contribution of the Mineral Bases

Now, besides acidosis of the fatty acid type, resulting from a disproportionate mixture of sugar and fat, a lack of balance between burning glucose and burning diacetic acid, there is another type of acidosis, called 'inorganic acidosis'. It is due to a lack of mineral elements in the diet which provide alkalis. These mineral alkalis neutralize acids by combining with them to form salts. The organic constituents of a diet, the proteins, the fats, and the sugars, are constantly forming acids, such as lactic acid, carbonic acid, phosphoric acid, as end products of their metabolism. The mineral alkalis must be depended upon to counteract their deleterious effects.

Consequently, these mineral elements assume most important roles in nutrition, even though they have no value from the viewpoint of their energy value. Moreover, they act as the electrical catalysts of the chemical reactions of life. They electrify the energy-yielding foods associated with them, reacting with the dead carbonaceous and nitrogenous matter of life. These effects, called 'ionization', seem to generate the essence of life.

But mineral elements are by no means all neutralizing. Associated with the proteins, fats, and starches, as they occur in natural foods, occur certain of the acid-forming minerals. In the course of their adventures in metabolism, they are oxidized into organic salts. Such are sulphur which forms sulphuric acid, phosphorus which becomes phosphoric acid, chlorine which forms hydrochloric acid, fluorine which can be-

come hydrofluoric acid, and iodine which can become hydriodic acid, arsenic which forms arsenious acid, and silicon which makes silicic acid.

To neutralize these seven acid minerals (predominantly the sulphuric and the phosphoric acids) there are at least seven basic alkaline minerals. Sodium, potassium, calcium, and magnesium, iron, manganese, and copper. Of these the really important ones for acid neutralization and the prevention of inorganic acidosis are the first four: sodium, potassium, calcium, and magnesium.

The latter three, iron, manganese, and copper, are important for the fundamental function of blood formation. They manufacture the red cells in the bone marrow. Anaemia accompanies deficiency of one or another of the triad.

These inorganic or mineral elements of foods, occurring as they do in connection with the burnable organic compounds, may be compared to the ash left in a furnace after fuel combustion. The ash may vary in its alkalinity and may even be acid. If a diet over a period of time has an ash which is acid rather than basic, or is insufficient to neutralize the total acidity of metabolism, there occurs a lowering of the reserve alkali. What is called acidosis is really a diminished alkali reserve.

Acidosis does not necessarily lead to immediate disaster, but may injure the kidneys and ultimately produce uraemic coma. People affected with inorganic acidosis lack energy and complain of an inability to concentrate upon their work, as well as a causeless irritability. There may be, but not necessarily, general joint and muscle pains, burning urine, and sometimes a migraine variety of headache. Some conception of the possibilities may be attained by comparing tables of alkali-producing and acid-forming ones, rated on a relative scale.

It is obvious that in general it is the fruits, vegetables, and green leaves that furnish the alkaline minerals, while the animal foods and the cereals give the acid.

Sodium is also added to the diet, artificially, as table salt.

Sulphur is found most conspicuously in cabbage, cauliflower, Brussels sprouts, onions, and eggs.

Phosphorus is present in large quantity in milk, cheese, and unmilled cereals.

Acid ash (inorganic acidosis) is preventable by balancing the acid-ash foods with the alkaline-ash foods. Oranges,

lemons, grape-fruit, apples, melons, bananas, and potatoes act as antidotes to the acidogenic cereals, fish, flesh, and fowl.

It has been emphasized by several observers that an acid diet may be a cause of high blood pressure and its accompanying injurious consequences for the brain and mental activity. In such cases it is found that the urine is excessively acid. Also the blood pressure decreases considerably when the urinary acidity is diminished by dietary measures.

Acid-Base Balance in Foods on Scale of 100 for

Alkali-Producing Foods.		*Acid-Producing Foods.*	
Molasses	100·0	Egg yolks	100·0
Raisins	47·5	Oysters, fresh	60·4
Beans, fresh Lima	25·0	Shredded wheat	48·8
Almonds	21·9	Oatmeal	48·0
Parsnips	21·2	Sardines	45·2
Dates	19·6	Eggs, whole	44·0
Beets, fresh	19·4	Beef, Porterhouse	43·6
Carrots	19·2	Chicken	42·8
Figs	17·8	Salmon, tinned	41·6
Swedes	15·1	Barley	41·6
Cucumbers	14·1	Pork, lean	40·0
Celery	13·9	Veal loin	39·2
Melon	13·3	Ham, smoked	38·8
Lettuce	13·2	Beef ribs, lean	38·4
Potatoes	12·5	Mutton leg	38·4
Coconut	12·5	Rice	37·2
Pineapple	12·1	Halibut	37·2
Sweet potatoes	11·9	Trout, salmon	35·2
Plums	11·0	Crackers, soda	33·2
Cabbage	10·7	Walnuts	31·2
Bananas	10·0	Bread, whole wheat	29·2
Oranges	10·0	Bread, white	28·4
Tomatoes	10·0	Perch	25·2
Lemons	9·8	Corn	23·6
Beans, fresh string	9·6	Cheese, Cheddar	21·6
Peaches, fresh	8·9	Lentils	20·4
Mushrooms	7·1	Bacon	20·0
Grapejuice	6·9	Egg white	19·2
Apples	6·6	Peanuts	15·2
Pears	6·4	Corn, green	7·2
Radishes	5·1		
Milk, whole	4·1		
Onions	2·6		
Peas	2·3		

Not only in cases of high blood pressure, with and without signs of damaged kidneys, but also in the cases of low blood pressure, the urine may be altogether too acid. When the diet is modified so as to be predominantly alkaline, satisfactory rises of the blood pressure occurred. At the same time hypodermic injections may be given of glandular extracts which depress the sympathetic nervous system, overactive in these individuals. Also there occurs a complete relief of annoying or disabling symptoms such as: headache, numbness of the hands and feet, inability to concentrate, and alarming fatigability.

The best practical means of ascertaining the degree of acidity of the tissues is to determine the reserve alkalinity or bicarbonate of the blood. This can be compared with the total acidity of the urine. For routine purposes, a comparison of the acidity of the evening urine (under ordinary fluid intake) with that of the morning urine is valuable. There must, of course, be no sign of inorganic disease of the kidneys.

The Blood-Formers

Many songs have been sung in recent years concerning the virtues and powers of the mineral salts in nutrition. It is true that the alkalinizing contribution of food is as fundamental as the others. But there is no need for exaggerating the role played by them in adequate or optimal nutrition. There may be enough of them, but a deficiency of the other essential constituents of a diet may produce effects just as disastrous as a lack of any one of the minerals.

The alkalinizing function of the minerals is not by any means the only function to be ascribed to them. There are a series of mineral elements which, occurring only in traces as compared with the alkalinizing ones, exert influence as catalysts of metabolism in general and of blood-formation in particular. They are iron, copper, manganese, zinc, and aluminium. They have come to occupy an important place as the 'Little Giants of Nutrition', because they are active in amounts so diluted that they invite comparison with the tremendous powers of tiny quantities of the hormones of the endocrine glands and the vitamins of food.

Of these, iron is present in the greatest amount. Yet the iron content of the average adult human body is only about one part in twenty-five thousand. It is the only one of this

group of minerals which has a structural as well as catalytic function in the bodymind, for it enters directly into the construction of the haemoglobin of red blood corpuscles. These corpuscles are the oxygen-carriers of the circulation and therefore the link between the breathing of the lungs and the breathing of the internal organs. Anaemia, a deficiency of the red blood corpuscles or of their haemoglobin or both, means poor internal breathing of the cells. Thus not enough oxygen being delivered to them, there develops the condition of oxygen starvation known as ' anoxaemia '.

Besides, iron acts as an oxygen-carrier in all cells. It is a necessity for the continuous oxidations of metabolism which are the essence of life. There is very little stored iron for the organism to call on in case of need, as there is in the case of salt, sodium chloride, which is stored in the skin, or lime in the bones. So that if the income of iron in a diet does not equal the inevitable daily loss of it in the wear and tear of daily metabolism, haemoglobin manufacture is necessarily curtailed and anaemia results.

Red cells live about thirty days. New ones are being created all the time to replace those which die. Whether they are rich in haemoglobin, or poor in it, they must be mobilized to carry on in the blood stream as best they may. Anaemia means anaemic red cells. In addition an insufficiency of iron means a failure of its other catalytic functions, especially in the brain and muscles.

For a long time there was much controversy concerning whether medicinal iron (pure iron salts) was just as available for the formation of haemoglobin as the iron in foods. It may be taken as well established that inorganic iron may so function. But the cheapest, easiest, and most readily applicable way of supplying necessary iron is by way of foods containing respectable quantities of it, as the table on the following page shows.

The Iron Deficiency of Milk

In the last few years milk has been boomed as the nearly perfect food. That it is a perfect food is about to become one of the superstitions of the housewife of the twentieth century. Besides a number of other objections against that new dogma, one of the most important is the fact that it is markedly lacking in iron.

Because Nature has made milk the sole food of infants during the suckling period, an extra supply of iron and the other minerals useful for blood-formation is present in the liver of the new-born. Out of the mother's body, iron and other minerals are taken and stored in the liver of the child in the womb during the last three months before birth. Guinea pigs, and other animals which feed on green leaves and other iron-containing food immediately after birth, have no reserve store of iron in the liver. That is because they are born with teeth and can chew and digest coarse food the day they are born.

IRON IN TYPICAL FOOD MATERIALS

Food	Iron per 100 grammes fresh substance, milligrams	Iron per 100 grammes protein, milligrams	Iron per 3,000 calories, milligrams
Egg yolk	8·6	53	69
Beans, dried	7·0	40	60
Peas, dried	5·7	23	46
Wheat, entire grain	5·0	37	42
Almonds	3·9	19	18
Beef, all lean	3·86	16	97
Oatmeal	3·8	22	26
Spinach	3·6	135	450
Eggs	3·0	22	57
Prunes, dried	3·0	143	30
Beefsteak, medium fat	2·2	16	47
Walnuts	2·1	11	9
Peanuts	2·0	8	11
Potatoes	1·3	55	42
Cheese	1·3	5	9
Beans, string, fresh	1·1	48	80
Cabbage	1·1	69	104
White flour	1·0	7	7
Rice, polished	·9	11	7
Corn, sweet	·8	26	23
Bananas	·6	47	18
Carrots	·6	55	40
Turnips	·5	39	38
Apples	·3	78	15
Milk, skimmed	·25	7	30
Milk, whole	·24	7	10
Oranges	·2	25	12

The percentage of iron in the liver of human beings at birth is about enough to carry them through the first year.

Whether anaemia, due to a lack of iron, will develop, depends upon what the mother's food and health have been during pregnancy and the age of the infant when born. A prematurely born infant, a twin, or one developing rickets is insufficiently equipped at birth with the precious metal. In the absence of an excess of iron-containing foods in their diets they will evolve an anaemia.

Recent reports of Weston emphasize that the milk of cows feeding upon mineral-rich herbage (due to the mineral wealth of the underlying soil), such as the blue-grass country of South Carolina, contains enough iron to prevent anaemia. It is quite possible that the milk of the future may be obtained from cows so fed and treated in the light of modern knowledge. Milk so treated may ultimately make it the ideal food it is now supposed to be, provided its other deficiencies are also corrected by special feeding of the cow.

Iron is not the only element concerned in blood-formation. Attention to this was directed by one of the most interesting by-products of a research on the liver in pernicious anaemia. Copper was discovered in the ash of liver. This research was stimulated by the finding that liver and liver extracts possessed what seemed to be curative powers in pernicious anaemia.

As there is a red, iron-containing oxygen carrier, haemoglobin, in land animals, so there is a blue, copper-containing oxygen carrier, haemocyanin, in the creatures of the sea. Copper is also present in the human brain and in the human blood serum. Even cow's and human milk constantly contain some traces of copper. It is present in oysters, chocolate, cocoa, and molasses. But fresh calves' liver is the highest in copper.

McHargye, Healy, and Hill carried out an interesting experiment on the relation of copper to blood-formation. Dried calves' liver was ashed and divided into equal portions. From one the copper was removed. Then the copper-containing ash was fed to a group of rats which had been on a milk diet for four weeks and had consequently developed anaemia. At the same time the copper-free ash was given to a second batch of rats also made anaemic by milk feeding. At the end of six weeks the haemoglobin of the blood was determined in the two groups. The one receiving the copper-containing ash were definitely richer in haemoglobin. Because of the

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external appearance of the animals, the colour of their fresh blood, and the haemoglobin readings, the experimenters concluded that 'copper has an important function in the formation of haemoglobin and in the metabolism of animals having red blood'.

This work was preceded by that of Hart and Steenbock, who found that the ash of beef liver or dried lettuce could raise the haemoglobin of anaemic rats to a normal level. An equivalent amount of pure iron salts was ineffective. If copper was mixed with the iron, though, the anaemia could be cured. There was general all-round improvement at the same time, increased appetite, smoother hair, and more activity. In 1927, Cohn and his associates found that the curative property of liver in pernicious anaemia was due to the presence of a water-soluble substance practically free of iron. Hart reported that it contained copper. But it was incapable of curing the dietetic anaemia of rats unless combined with iron.

A third element which occurs in relatively small quantities, but is a necessity of health, is manganese. It appears in largest amounts in the liver, pancreas, lymph nodes, and kidneys. A fairly constant concentration of it characterizes the blood. As regards food, it occurs in the greatest amount in beet tops, blueberries, lettuce, pineapple, and wheat bran. Lavine reported in 1904 that when young rats on an adequate diet were given manganese in their drinking-water, they were better nourished and more active, and their offspring grew faster.

A most interesting research is that of Titus, Cave, and Hughes, reported in 1928. In studying the milk anaemia of rats they discovered accidentally that some were cured with certain kinds of iron and remained anaemic with others. Analysis revealed that the curative iron samples contained manganese. Also manganese was not quite as good as copper as a supplement to iron in the prevention and treatment of anaemia. But the best results in anaemia are obtained when iron, copper, and manganese are mixed in the proper proportions.

Pyrrole and Pernicious Anaemia

No matter how well balanced a diet may be in respect to the minerals (iron, copper, and manganese), adequate blood-

formation is not ensured unless the other elements entering into the constitution of haemoglobin are present. Haemoglobin is a compound of the red iron-containing pigment—haematin, and a protein of the histone group—globin. For the formation of globin, a large amount of the amino-acid histidine is necessary. Relatively little histidine is contained in milk.

For the construction of haematin there are needed foods containing the pyrrole ring. The pyrrole ring is one in which there are four carbon atoms linked with one nitrogen atom. This pyrrole ring cannot be synthesized by the animal organism. It is contained in the amino-acids: prolin, oxyprolin, glutaminic acid, and tryptophane, as well as in chlorophyl, the green pigment of plants. Chlorophyl is not digested by the intestinal juice, but it may be split up by the intestinal bacteria and thus made available for absorption.

The pyrrole ring forms the nucleus for the substance, haematin, which becomes linked with iron to form haemoglobin. It is, therefore, the skeleton of haemoglobin. Under ordinary conditions we are dependent for a supply of the pyrrole ring (without which anaemia is inevitable) on the amino-acids present in various proteins. And again it is very interesting to note that there is very little of them in milk proteins.

It is remarkable that, while it was predicted more than ten years ago that anaemia would result if there was an absence of pyrrole-ring-containing material in a diet, it was not until the story of the relation of liver to pernicious anaemia was unravelled that the definite proof came to hand. This disease, once called the progressive anaemia of Addison and Biermer, was formerly considered a chronic disease. It had a tendency to a fatal outcome and with as hopeless a prognosis as cancer has to-day.

Before the introduction of liver feeding, pernicious anaemia was generally considered due to a poisoning of the bone marrow. The abnormal blood picture was in favour of that view, as were the findings in the bone marrow. The blood shows a marked reduction in the red cells, which are deformed, and either too small or too large. The white cells of the blood are also diminished. A peculiar red marrow replaces the yellow fatty marrow normally found in the bones.

Spontaneous remissions characterize the disease. Then the blood, as well as the bone marrow, return to normal and the patient feels well. Now this fact should have held out hope of finding a cure. The art of medicine consists in imitating Nature and these remissions represented Nature's attempt to cure. It was noticed that those periods of remission were preceded by an outpouring of very young nucleated red cells, the reticulocytes. Then Whipple reported the efficacy of liver feeding in curing anaemia produced by simple bleeding, Minot and Murphy applied his discovery to their cases of pernicious anaemia. They were able to demonstrate great improvement, preceded and accompanied by a mobilization of reticulocytes from the bone marrow into the blood.

It was then shown by Cohn and his associates that a watery extract of the liver made by heating it at eighty degrees Centigrade in acid solution was equally efficacious. But the liver ash, containing the minerals, had no ability to mobilize reticulocytes. Most recently the active anaemia-curing substance of liver has been extracted by various methods and obtained in a very powerful concentrated form. It may be related to the amino-acids which contain the pyrrole ring, glutamic acid, and oxyprolin. Liver extract is now available for hypodermic use, which makes it unnecessary to take liver by mouth if it is distasteful.

Equally important are the experiments of Castle, throwing light on the nature of pernicious anaemia and the blood-forming prerequisites of a diet. First, he found there was no change for the better if the patient was fed half a pound of lean meat daily. But if the meat was first eaten by a normal individual, regurgitated after about half an hour, incubated with hydrochloric acid, and then fed, the reticulocyte reaction and the general improvement was the same as that following liver treatment. It was known that the pernicious anaemics had a condition of atrophy of the stomach with complete absence of its digestive juices, a lack of pepsin and hydrochloric acid, a condition called *achylia gastrica*. It sometimes precedes the appearance of anaemia in the history of the course of the disease by as much as ten years.

Castle conceived his ingenious experiment as an attempt to combat the *achylia gastrica*. Upon the basis of his work, extracts of stomach, called 'ventriculin', have been prepared

and successfully used in pernicious anaemia. Thus even tripe has come into its own!

The upshot of all these investigations on the relation of liver, kidney, meat, and stomach to anaemia is that pyrrole-ring-containing substances must be present in a diet. They may appear in free form as in kidney and liver. Or if they occur in a combined form, as in meat and other foods, they must be liberated to form essential building-blocks for red cells. Iron, copper, manganese, and the pyrrole ring are the dietetic requirements for adequate blood formation. Also they prevent deficiency disease. Different individuals need differing amounts of these, which in special cases must be specifically determined in order to keep them in the best of health.

The Vitamins—Minute Indispensables of Diet

About twenty years ago, Funk introduced the term 'vitamin'. The word then was coined for the substance in food which prevents the disease beri-beri. He claimed to have isolated it, in an approximately pure state, from rice polishings. When added to a diet of polished rice, it could cure the form of beri-beri experimentally producible in pigeons, called 'polyneuritis'. He prophesied that a whole series of substances would be found capable of preventing and curing deficiency diseases. His predictions have not only been correct, but have revolutionized the whole field of nutrition and dietetics.

At present a number of different substances have been classified as belonging to the vitamin group. The name 'vitamin' has become current for all of them because they act in such remarkably small amounts and are essential to vital functions and organs of the bodymind. Those named are Vitamin A, B, C, D, E, F, and G.

Vitamin A is a substance essential to the growth and maintenance of the bodymind, as well as resistance to disease. It specifically protects against the infectious disease of the eyes known as 'zerophthalmia'. The first stage is a tendency for the lacrimal glands to pass into a state of inactivity and so to cease producing tears. So the eye chamber is no longer washed continually as is usual and normal, and bacteria get their chance to accumulate and grow. This absence of the functioning of the glands is due to a change in the

character of their cells. The normal cube-like cells become flattened into skin-like cells. Similar changes occur in the mucous membranes of the nasal passages, the larynx, trachea, and bronchial tubes, the salivary glands, the bladder, and the prostate gland. Vitamin A protects all of them against infection, and indeed seems to act as a protective against infection in general.

Now, if Vitamin A is specifically necessary for the maintenance of the normal condition of these glands and mucous membranes, the Vitamin A content of the diet should be carefully scrutinized in all infections. It is abundant in milk, cream, butter, cod-liver oil, the internal glandular organs such as kidney and liver, all leafy vegetables and yellow pigment vegetables that contain carotene (which gives the characteristic colour to carrots). It has been shown recently that carotene is the chemical precursor of Vitamin A in animal metabolism. An enzyme in the liver transforms carotene into Vitamin A and it will not be long before Vitamin A is obtained in crystalline form.

Vitamin B is the anti-beri-beri preventive. It protects against neuritis. The first tissue to suffer from a deficiency of it is the nervous system and particularly the peripheral nerves. It is present in all fresh animal and plant food. But it tends to be destroyed in time by drying and by various methods of treatment. The efficacy of raw foods in various conditions is probably due to it.

Vitamin C prevents and cures scurvy. It is abundant in oranges, lemons, and the other citrus fruits. The first tissue to be affected by the lack of it is the gums, which begin to bleed. It has been said to act as the great binding substance of cells, for tissues become spongier and looser in its absence.

Vitamin D prevents and cures rickets. It is present in fish-livers, cod-liver oil, egg yolk, various fish, and internal glandular organs. The tissues most easily and earliest affected by its inadequacy are the bones.

Vitamin E is necessary for fertility and reproduction. It occurs in whole cereal grains and leafy vegetables. A specific relation to the sex organs is peculiar to it. In the male the tissues most easily affected are the testes. In the female it is the placenta, the peculiar organ formed in the abdomen which nourishes the embryo that is soonest involved.

Vitamin F is a substance necessary for the normal growth

of children, for the maintenance of appetite, and for the adequate tone, motility, and functioning of the stomach and intestines, small and large. It is found in yeast, milk, and various fruits and vegetables.

Vitamin G is the preventive for pellagra. The first tissue to be affected by its absence or deficiency is the skin and its appendages, the hair and nails. It is lacking in corn meal, white flour, milled rice, cotton-seed oil, and probably other oils. The foods which contain it in largest amounts are yeast, lean meat, milk, and eggs, in the order named.

There are other vitamins in the group known as the Vitamin B complex. Knowledge of these is still in the purely laboratory stage.

These vitamins, essential to normal life in small amounts not influencing the energy content of a diet, are the most important catalysts of the dynamic chemistry of bodymind. They affect different tissues in a specific way.

McCarrison, an active student of the vitamins, has promulgated the following twenty principles concerning the relation of the vitamins to diet and metabolism :

1. Vitamins are constant constituents of living tissues. Although present in very small amounts, maintenance of health is dependent on their action.

2. Vitamins do not themselves contribute to the energy supply of the body, but facilitate utilization by it of proteins, fats, carbohydrates and salts of food.

3. Proteins, fats, carbohydrates and salts cannot support life without vitamins, nor vitamins without these proximate principles : they are complementary to each other. Without vitamins the body starves.

4. A distinct relationship exists between the amount of vitamin required and the balance of food in protein, fat, carbohydrate and salt, the efficacy of the vitamin depending on the composition of the food mixture.

5. A distinct relation exists between the amount of vitamin required and the rate of metabolic process.

6. Each vitamin plays a specific part in nutrition.

7. It appears that Vitamin A is associated with the metabolism of liquids and calcium, as well as with chemical reactions requisite for growth and maintenance.

8. Vitamin B appears to be associated with the metabolism of carbohydrates and with the chemical reactions and functional perfection of all cells, particularly nerve cells.

9. Vitamin C appears to be associated with the metabolism of calcium and with chemical reactions of growing tissues.

10. All vitamins are concerned in the maintenance of orderly balance between the destructive and constructive cellular processes.

11. One vitamin cannot replace another although its function may be interfered with by the absence of the other.

12. The final result of their deficiency is the same whatever be the degree of deprivation. The greater the deprivation the more rapid is the onset of symptoms due to it; the lesser the deprivation the slower is the onset of the symptoms due to it.

13. Each vitamin exercises a specific influence on the adrenal glands; the effect of their deprivation on these organs is one of the most outstanding features of deficiency diseases.

14. Vitamins influence markedly the production of hormones and all external secretions.

15. There is reason to believe that the capacity of any given cell for work is impaired in proportion to the degree of vitamin starvation.

16. Vitamins aid the tissues in resisting infection.

17. Vitamins, especially Vitamin B, induce in the human and animal body the desire for food.

18. Vitamins are one link in the chain of essential substances requisite for harmonious regulation of chemical processes of healthy cellular action. If the link be broken harmony ceases or becomes discord, as it may cease or become discord if any other link is broken.

19. The place of vitamins in human economy must be considered in connection with metabolism as a whole; in connection with their relation to other essential food requisites, with their relation to organs of digestion and assimilation, and with their relation to endocrine regulators of metabolic processes.

20. Vitamins are the spark which ignites the fuel-mixture of a petrol-driven engine, liberating its energy; a spark is of no use without fuel, nor fuel without spark—nay more, the efficacy of the spark is dependent in a great measure on the composition of the fuel mixture. What happens (when the body goes sick in consequence of deficient food, usually ill-balanced) is this: in the absence of vitamins or in an adequate supply, proteins, fats, carbohydrates and salts are not properly utilized; some are largely wasted, others yield products harmful to the organism. In these circumstances life may be sustained for a longer or shorter period, during which the body utilizes its reserve stores of vitamins and sacrifices its less important tissue to this end. But there is a limit beyond which such stores cannot be drawn upon, and once reached, the cells of higher function—secretory, endocrine and nerve cells—begin to lack vigour and depreciate in

functional capacity, although the tissues may hold considerable stores of vitamin. The disintegration process is delayed or hastened, lessened in severity in one direction or increased in another, according as the food constituents are well or ill balanced and according to the character of lack of balance.

The lack of vitamins disturbs the calcium metabolism ; puts an end to regenerative processes ; involves the cells of higher function, causing a functional depression of many a death and failure of a few. The cardinal effect is depreciation of cellular function, and this depreciation is the foundation upon which disease is built.

This conception of the function of vitamins holds out promise in the cure of disease due to or favoured by their deficiency in food ; for though they cannot restore to life cells already dead, they can restore to normal depressed functional capacity in the general mass of the body's cells. The conception that vitamins provide the cells of the body with power—one might almost say will—to do work, has this great merit, that it furnishes a working hypothesis on which to frame treatment.

The newer knowledge is, I am convinced, the greatest advance in medical science since the days of Lister. When physicians, medical officers of health, and the lay public learn to apply the principles which this newer knowledge has to impart, when they know what malnutrition means, when they look upon it as they now look upon sepsis and learn to avoid the one as much as they now avoid the other, then will this knowledge do for medicine what asepsis has done for surgery.

A very interesting and fairly inclusive chart describing much of what is known of the vitamins has been compiled by Weston and Levine and published by the South Carolina Food Commission.

Name	Descriptive Name	Functions in the Body	Results of Deficiency or Absence
Vitamin A	Anti-ophthalmic Anti-infective	Prevents infections, notably of eyes and respiratory system. Promotes growth and longevity. Maintains health and vigour. Promotes appetite and digestion. Essential for normal reproduction, lactation and rearing of the young. Maintains the integrity of the epithelial tissues.	Lowered resistance to infections. Retardation of growth and development. Susceptibility to infections of the (*a*) glands at the base of the tongue (abscesses), (*b*) sinuses (pus) and ears (otitis media), (*c*) eyes (night blindness and xerophthalmia), (*d*) tear glands (loss of power to produce tears), (*e*) salivary and lymph glands, lungs, nose, skin, (*f*) kidney, ureter, bladder (calculi), (*g*) alimentary canal. Diarrhoea, physical weakness. Failure of appetite and digestion. Sterility due to failure of ovulation. Cornification of secreting epithelium.
Vitamin B (B_1) (F)	Anti-neuritic Anti-beri-beri	Promotes appetite and digestion. Promotes growth by stimulating metabolic processes. Protects body from nerve disease (beri-beri, polyneuritis). Required by the mother for normal reproduction and lactation. Promotes tonicity of the digestive tract.	Impairment or loss of appetite. Impairment of digestive processes (decreased motility of the stomach, atonic intestines). Impaired growth of young in lactation period (due to deficiency in mother's milk). Sterility due to cessation of the œstrus cycle. Anhydremia. Loss of weight and vigour. Subnormal temperature. Fatigue.

Name	Descriptive Name	Functions in the Body	Results of Deficiency or Absence
			Beri-beri or polyneuritis, (*a*) loss of co-ordinating power of the muscles, (*b*) gradual paralysis of limbs, (*c*) alimentary disturbances (indigestion, constipation, colitis), (*d*) emaciation.
Vitamin C	Anti-scorbutic	Protects body from scurvy. Required for proper metabolism of the bones. Required for normal tooth formation and maintenance.	Scurvy. (*a*) Haemorrhages (mucous membrane, skin, joints, limbs, and bone marrow), (*b*) spongy and bleeding gums (ulcerations), (*c*) bleeding muscles and joints, (*d*) pains and swellings in joints and limbs, (*e*) fragility of bones (spontaneous fractures). Decalcification of bones. Decay of teeth. Loosening and shedding of teeth. Loss of weight. Fatigue. Loss of appetite. Sallow or pallid complexion.
Vitamin D	Anti-rachitic	Regulates the absorption and metabolism of the bone-forming elements—calcium and phosphorus. Regulates the mineral metabolism of the bones and teeth. Required by pregnant mother to prevent rickets in young.	Rickets (bone disease). Deformities of bones : (*a*) soft and fragile bones. (*b*) enlargement of wrists and elbows. (*c*) enlargement of rib junctions. (*d*) bulging forehead. (*e*) softening of cranial bones. (*f*) delayed closing of fontanels.

Name	Descriptive Name	Functions in the Body	Results of Deficiency or Absence
Vitamin D (*continued*)			(*g*) malformation of chest and pelvis. (*h*) bowed legs. General muscular weakness and instability of nervous system. Faulty absorption, retention and deposition of the bone-forming elements — calcium and phosphorus—in the body. Low content of calcium and phosphorus in blood and bones. Defects in teeth (caries, poorly calcified teeth)
Vitamin E	Anti-sterility	Essential for normal reproductive function (*a*) Required for normal germ cell maturation in male. (*b*) Required for normal placental function in female.	Failure in reproduction (sterility) : (*a*) degeneration of germinal epithelial in male. (*b*) failure in placental function in the female. (*c*) disturbance in gestation (death and resorption of developing young).
Vitamin G (B_2)	Anti-pellagric	Prevents pellagra *	Pellagra : (*a*) alimentary disturbances. (*b*) dermatitis. (*c*) pigmentation and thickening of the skin. (*d*) soreness and inflammation of tongue and mouth. (*e*) diarrhoea. (*f*) nervous and mental disorders.

* The most recent experimental work indicates that there are other factors besides Vitamin G involved in the prevention or cure of pellagra.

Artificial Concentrates	Most Potent		Excellent		Good		
	Plant	Animal	Plant	Animal	Plant	Fruit	Animal
Non-saponifiable fraction of cod-liver oil Carotin * from carrots or green vegetables		Cod-liver oil	Lucern Broccoli Carrot Lettuce Spinach Tomato Watercress	Butter Cheese Cream Egg yolk Milk, whole	Artichoke Asparagus Cabbage Celery Sea-kale beet Clover Corn Chicory Kale Pea, green Pepper ,, Pumpkin String bean Sweet potato (yellow)	Apricot Avocado Banana Orange Peach Pineapple Prune	Clam Gland organs Liver Kidney Oyster (raw)
Vitamin B from yeast Vitamin B from rice polishings Vitamin B from wheat germs	Yeast		Cereals (whole) Wheat Corn Rice Oats, etc. Pea Wheat bran Wheat germ	Egg yolk	Asparagus Bean Cabbage Carrot Cauliflower Celery Kale Lettuce Onion Parsnip Potato Spinach Tomato Turnip	Apple Banana Cantaloup Date Grape Grapefruit Lemon Nuts Orange Peach Pineapple Prune Strawberry	Bran Cheese Fish roe Kidney Liver Milk Oyster (raw)

* Carotin is converted into Vitamin A in the body.

Artificial Concentrates	Most Potent		Excellent		Good		
	Plant	Animal	Plant	Animal	Plant	Fruit	Animal
Vitamin B from wheat germs (*continued*)					Turnip green Watercress		
Vitamin C from orange juice Vitamin C from lemon	Vegetables Cabbage Lettuce Onion Spinach Tomato Tomato juice Fruits Lemon Orange	Animal sources as a class are practically devoid of Vitamin C	Vegetables Celery Rhubarb Turnip Fruits Citron juice Lime juice Peach Pineapple Raspberry Strawberry Tangerine		Vegetables Bean Beet Cabbage Carrot Cauliflower Kale Cucumber Endive Pea Pepper Potato Pumpkin Spinach Sweet corn Turnip green Watercress	Apple Banana Grape Grape juice Pear Watermelon	Milk variable
Ultra-violet light from arc lamps Non-saponifiable fraction of cod-liver oil Ergosterol irradiated with ultra-violet light Foods irradiated with ultra-violet light	Plant sources as a class are generally devoid of Vitamin D	Cod-liver oil Sunlight direct, most potent in summer		Egg yolk Salmon			Butter variable

Artificial Concentrates	Most Potent		Excellent		Good		
	Plant	Animal	Plant	Animal	Plant	Fruit	Animal
		The ultra-violet component of sunlight and Vitamin D are interchangeable as anti-rachitic agents					
Non-saponifiable fraction of wheat-germ oil	Wheat-germ oil		Lettuce Watercress Wheat germ		Lucern Barley Bean Corn Molasses Oats, whole Pea	*Oils* Cocoanut Cotton seed	Meat
Vitamin G from yeast	Yeast	Glandular organs Liver Kidney Spleen Lean meat	Beet green Kale Potato Spinach Turnip green Watercress Wheat germ	Egg Haddock Milk Salmon	Banana Beet Cabbage Carrot Lettuce Onion Tomato Turnip Wheat bran		

The Vitamins and the Ductless Glands

It is important, vastly important, to know which tissues are primarily affected by a vitamin lack, because it is probable that there is an affinity between special cells and particular vitamins. Thus, the early reaction of the gums to a lack of Vitamin C points to a much greater need for that vitamin on the part of the teeth-containing tissues. And recent reports have indicated that diseases involving the teeth and gums, such as caries and pyorrhoea, may be prevented or controlled by enriching the diet greatly with foods high in Vitamin C. By far the most important ones are the close relationships of the vitamins to the endocrine glands, the brain and the nervous system.

In studying the vitamin reactions of animals, large groups have to be studied and the results can be stated only in terms of averages. But human beings who present problems of ill health, mental disease or disturbances of character, cannot be treated as averages. There is a great individual variability in the need for various vitamins. It is the task of research to discover and explain the whys and hows of special individual requirements. Particularly, when there are indications of disease or poor physical and mental functioning, must therapeutic attention be directed to the question of specific nutritive needs. These include not alone the vitamins, but all the food requirements.

A recent publication of Alexander Cannon on beri-beri, which started the whole scientific study that has revolutionized dietetics, emphasizes the point. As a result of over two years' work with six hundred Chinese patients, he concluded that the background of beri-beri was a lack of balance of certain endocrine glands, making necessary a greater than average intake of Vitamin B (F). As a consequence, bacterial infection follows and the symptoms of disease. He found, for instance, that the sugar tolerance of those affected was about twice that of the normal individual, and a low blood cholesterol was constant. It is the trend of all modern thought on disease to regard an infection as engrafted on soil prepared by an endocrine-vitamin-nutritive imbalance. Without such receptive preparation, infection never occurs.

Individual variability, then, has always to be considered in the scrutiny of a diet which must always satisfy minimal,

as well as optimal requirements. These may be classified as : (1) calories (heat) ; (2) the glucose of sugars and starches ; (3) the unsaturated fatty acids of fats ; (4) the amino-acids of proteins ; (5) the alkalinizing mineral salts ; (6) the blood-forming mineral salts and pyrrolering; (7) the various vitamins.

An ordinary mixed diet generates these seven contributions to adequate nutrition after digestion and metabolic adventure. How they influence character and personality is a field that has begun to be penetrated. Much research has to be done, many detailed exact observations will have to be made. But the territory cleared is so interesting and its practical applications already so valuable as to make worth while the presentation of the conceptions and results now to be considered.

CHAPTER III

THE METABOLISM OF LEADERSHIP

NOW, if character may be affected so intimately by food, it follows that it ought to be possible to analyse various traits of character in terms of diet and metabolism. It ought to be possible to take a given characteristic of the behaving personality and state how the adventures of food in cells reflect themselves in the chemistry of souls. We have by no means attained a full and complete realization of that ideal goal. But it is possible to deal therapeutically with certain expressions of individuality that may be related to the effect of food elements upon the endocrine glands, and, through them, upon the brain and the nervous system.

One of the qualities of character which provides a scientific problem of the highest importance is that which goes under the name of ' leadership '. There are various unsatisfactory ways of stating what leadership is. It is really difficult to define comprehensively that something which makes certain human beings ' men of light and leading ', as Burke put it after Milton. They put themselves in that class because they possess the power, not only of mobilizing and charging their own energy at the highest possible pitch, but also of mobilizing and charging the energy of others. Their energy possesses a tension which overcomes resistance to their suggestions and ideas.

It is necessary, too, to distinguish between popular leadership and intellectual leadership. Intellectual leadership shows the way. It is steeped in the pioneering spirit which plunges on into the unknown of the farthest reaches of human thought. But popular leadership starts group movements and commands masses. By his ability to attract, convince, and organize a following, the leader then acts as a charging battery, influencing the

dynamics of the others of the group he is organizing or has organized.

Whatever the effects of such social magnetism may be, good or evil, the possession of the trait has always been admired and envied. 'Training for leadership' has become the well-known hackneyed phrase of college baccalaureate addresses. In a democracy, the education of political, social, financial pace-makers is a fundamental central problem. It is only in a genuine democracy of equal opportunity that the ideal conditions for the realization of a natural aptitude for leadership may be realized.

The theory of democratic society has always assumed that a group will choose the best leader to act as its directing head. Chosen for his wisdom or forcefulness, the best commander is the one who, under test, guides to victory, prosperity, and happiness. In practice, the leader, selected because of certain mob-appealing traits of his personality, may turn out to be a disastrous choice, entangling his followers in blunders and miseries. That is because superior intelligence, training, and ability are not necessary to the acceptance of leadership and leaders by the group.

The Characteristics of a Leader

The psychological characteristics of the leader vary with the numbers and complexity of the subordinated group. Leadership is always relative to the level of the led.

Among the apes, as in the group studied by Koehler, the leader was the one possessed of bulk and strength. He could pit the prestige of past performances against the recalcitrant or the insubordinate. Among human beings, mere physical bulk, sheer mass of flesh and volume of muscular strength, also contribute to the endowment of the leader. Business executives, it has been noticed, tend to be tall, large, and strong. A minority are or have been small, undersized, or frail. Among these latter a marked tendency to the development of a Napoleonic complex has been frequent.

In general the kind of ability spoken of as leadership is exemplified in organizing ability, political ability, military ability. It is therefore the kind of ability which exhibits itself in the manœuvring of masses of men in armies and navies and in the marshalling of voters and votes. Essentially it involves a voluntary or involuntary subordination

of individual wills to the leader's will by participators in any and every kind of group activity. It implies, therefore, a display of superiority by the leader: superior nerves, superior energy production and mobilization, an accompanying aggressive tenacity in the face of difficulties, superior endurance and resistance to fatigue.

It is the supposed or actual possession of these traits of superiority that make the leader the dominant person to whose rule his followers submit. By his past performances in the display of his qualities, the leader achieves that prestige of personality which affects the surrender of the ego of his following. Identification of the personality of the follower with that of the leader then occurs. Enlightened submission to a leader often means intelligent identification of the self-interest of the follower with that of the leader. The success of his cause is taken to be identical with the immediate or future welfare of those who follow him, be it in a political, economic, social, or cultural cause or crusade.

A study of genuinely successful leaders—those who have won enough support to carry their ideas to completion—shows that they do possess certain characteristics to an extraordinary degree. They have a nervous system which is relatively sensitive yet controlled. They may approach the borderland of the neurotic. They are dynamic in the sense of producing high voltage energy in quantities adequate for their needs. They can keep going and do keep going—with their minds, and, if necessary, with their muscles—because of a relatively low fatigability. They have keen social perceptions and generally lead an active sexual life.

The obvious superiority of the leader, however, must be only of a certain relative proportion. The field in which the follower can identify himself with the leader might be called the *range of identification*. For example, superiority of stature arouses the identifying tendencies of the group, and its suggestion of reserve strength is emotionally applauded. But a giant is rated an object rather ridiculous or ludicrous because he is outside the ideal standard of attainment. If the leader exceeds the *range of identification* of the follower, the superior quality becomes a handicap rather than an asset.

Similarly, intelligence, when out of reach of the common denominator of the group, comes to be looked upon as an incomprehensible monstrosity, worthy of neglect or ostracism.

Thus Hollingworth reports that a group of children will generally choose as leader a member of the class whose intelligence is above that of the average, but not too much. Consequently, children who are out of place in a class or group because their intelligence is too high are apt to be overlooked, snubbed, or maltreated. She cites an illuminating example of a boy who, in one class, was disliked by most of its members and considered rather a nuisance by his teachers. After examination had demonstrated him to own an intelligence far above that of his classmates, he was transferred to another class where his intelligence, still superior, was not so much out of proportion. Among the latter group he became quite popular and was elected president of his class.

In the practice of leadership all the traits of character, individuality, personality, are sharply tested. Even when the individual is being moved by the guiding lines of some distinguished leader of the past upon whom he models his present behaviour—the Napoleonic complex has been mentioned—he cannot go far in reality unless he is in possession of an unusual amount of the qualities mentioned. Otherwise, he will live his leadership solely in his dreams or his imagination, or else fall quickly by the wayside as soon as he attempts to realize his ambitions.

Several studies are available of the physique of those who have shown genius in leadership. And a number of books have been written on their psychology. Certain interesting suggestions have been made—such as that the focus of interest of the leader, the great cause for which he commands a crusade, is often the expression of some hidden fear, some unconscious moral conflict, which nowadays is labelled so glibly under the rubric of the 'inferiority complex'. It takes more than an inferiority complex, even a fanatical inferiority complex, to make a leader. Does it require certain biological foundations, a physiological equipment of a certain sort, a chemical apparatus which is the true accountant of the leadership drive?

What Ought to be Known about Leaders?

In short, to understand why one man leads, and another follows, only an understanding of the fundamental biological and chemical differences between them can satisfy us. Only then can we feel that we have attained a real solution of

the problem. Intelligent science ought to attain the knowledge by which it will be possible to control the leader's temperament and activities by the proper management of his chemistry. That would be the desirable end-point of our researches. As to who should be turned into a leader and who into a follower, that will be determined by the original tendencies of the inherited protoplasm. It will be easy to decide between the possibilities of the superior child and the possibilities of a moron.

A number of questions could be asked and answered immediately, if a certain number of the men and women who have made themselves the commanders of their fields would submit themselves for investigations. If Mussolini, Gandhi, Ramsay Macdonald, Stalin, Hitler, and other leaders could be studied from the standpoint of the chemistry of their blood, their basal metabolism, their reactions to food, and the response of their bodymind chemistry to dislocating and disarranging influences, a new view of the inequalities of men would be attained. The theory of democracy would have to be modified correspondingly. There are no reasons why such researches could not be carried out except the lack of a central co-ordinating institute where they could be started and maintained.

Some of the questions that might be asked and answered may be mentioned as an indication of how one would go about solving the problem. What, for instance, are the differences, if any, between the water content of the blood and tissues (the stability of hydration) between such men and the ordinary run of the populace? And directly connected with the aqueous metabolism are the issues of the salt, the sodium and potassium, chloride and phosphate differences. And the other minerals, so significant for the maintenance of the chemical and electrical stability of the bodymind, the calcium and magnesium compounds—how do they function in the rulers of mankind? And how about the lesser inorganic substances, such as manganese, copper, and cobalt?

From these the step to the consideration of the organic chemistry is obvious. How do leaders handle sugar, what are their glycogen reserves, how easily do they burn sugar, how quickly do they pay the oxygen debt, how often do they develop an acidosis? How much and what amino-acids do

they need specially, are they high or low protein people, what is their ability to deal with those most complex of the proteins, the purins, the metabolism of which seems to be intimately associated with the manifestations of genius ? What vitamins may be particularly good for them ?

What a precious collection of information could be gathered ! The practical applications would follow almost automatically. In addition, test would be made of the vital functions of the endocrine glands, which regulate these diverse chemistries. Insight then could be attained into the *why* and the *how* of the discovered chemical differences between the great leaders and those who must needs follow them.

The laws underlying the appearance of the outstanding figures who have dominated the progressions and retrogressions of the human race would gradually unfold themselves. There has been much discussion concerning whether the public needs or the individual leader's needs have been paramount in determining the course of history. But there can be no doubt that the ideas and activities of the leader, religious, fanatical, paranoiac, or whatever they may be, have contributed massively to the total configuration. The leader and his group environment interact as does the individual and his particular surroundings. In both, food and the endocrine glands are decisive.

Present Possible Explorations

In the absence of such an ideal series of data on the metabolism of the commanding personages of our time, it becomes necessary to fall back upon what can be gathered indirectly about them. Several ways of approach are possible. We have at our disposal photographs which reveal a certain amount of the glandular constitution of our subjects. As the particular type of glandular constitution or personality is accompanied by a predictable type of metabolism, which is the resultant of the glandular type, certain deductions become probable. These, of course, have to be verified by the direct determination of the data involved. The observations would have to be checked and assured before the conclusions could be considered an acceptable basis for generalizations.

To the photographic diagnosis of the glandular make-up may be added another series of data which have an especial interest for us. That is, what do these leaders of men eat ?

What do they have for their meals regularly? What have they discovered, by personal experience, is best for them and what worst? What outstanding likes and dislikes in the way of foods are theirs?

Special likes and dislikes of certain foods are often the expression of metabolic tendencies decided by the domination or inferiority of one or another of the glands of internal secretion. The hyperthyroid dislikes sugars, the adrenal deficient turns away from fats, the pituitary failure craves salt, sweets, and oils, the parathyroid-centred loves acid and sour things. Taking all data in conjunction, physique and behaviour may be correlated with the 'chemique'. And all three combine to procure for us a new picture of those characteristics of the 'psychique' which function in the social system as 'leadership'.

We must endeavour, then, to find out: How much water or how little does the leader under scrutiny consume? How easily does he become thirsty and for how long can he go without water? How much salt does he crave and how heavily does he tend to salt his food? What are the effects of the withdrawal of salt from his diet? How much sugar and starch does he tend to partake of as the average quota of the twenty-four hours of the day? How much fat, animal or vegetable, in the form of milk, cream, butter, lard, or vegetable oils enter consistently into his food régime? And how much protein provides for him his average intake of the amino-acids and the nucleic acids? How much acid, how much of the green leaves, the vegetables, roots and tubers contribute to the balancing of his diet? Is there any tendency to exaggeration or deficiency of one or another of the important vitamins which have so fundamental an effect upon the endocrine glands, supplying as they do either the raw materials or the catalysts for the hormones to be manufactured by them?

All these queries are part of the systematic questioning to which those with symptoms of possible glandular disorders are subjected because the answer to them may throw light upon their underlying endocrine imbalance. But they may also be used in the study of normal constitution, normal body-mind, and the normal glandular tendencies of the personality. Leading men and women might provide the most valuable kind of information by their specific answers to these ques-

tions. Certain leaders have put themselves on record as recognizing the importance of diet in making them what they are, or in keeping them what they are. Few, however, have recognized any connection between their food and the qualities which they regard as essential to their commanding position.

The Food Habits of Leaders

In his play, *Caesar and Cleopatra,* George Bernard Shaw presents Julius Caesar's favourite tipple as barley water. At the great banquet which Cleopatra had arranged in his honour, that is what he requests in place of the celebrated wines proffered him. He also prefers oysters to peacocks' brains, nightingales' tongues, and sea hedgehogs. Caesar may not have been as abstemious in his youth, but he evidently had the wisdom to discover and apply what was good for him. Nor did it take a complete breakdown of his health to make him as careful as Cornaro.

On the other side, there is the case of Bismarck, who remained a glutton until the end of his life. In a letter written in his youth during a visit to England, he writes, with what he evidently intends to be a tone of joyful approval: 'This is the country of great eaters. . . . Your food is not served out to you in helpings. Huge joints, bigger than can be imagined, stand before you on the table, and you cut and eat as much as you please, without its making any difference in the bill.' [1] Bismarck indulged in enormous meals until the end of his life. One typical meal, for instance, consisted of soup, plump trout, roast veal, and three large sea-gulls' eggs, and caviare, washed down with much beer and burgundy. Another meal consisted of soup, eels, cold meat, prawns, lobster, smoked meat, raw ham, roast meat, and pudding. At the age of sixty-eight, he weighed two hundred and forty-seven pounds and was so bloated that he was considered to be dying of cancer of the liver. A doctor named Schweninger exploded that diagnosis by putting him on a diet of herrings only. He lost considerable weight and regained part of his health.

There are those who would correlate these prodigious indulgences in food with the coarse brutality and the 'blood-and-iron' policy of the Chancellor who made the Empire

[1] Quoted from Ludwig's *Bismarck.*

of Germany and prepared the way for the World War of 1914–18 and the consequent *débâcle* of European civilization. The contrast of his food habits and life methods with those of his contemporary, Gladstone, is striking. Gladstone's attitude toward life made him the darling of the English middle class. A dietary practice which endeared him to *Punch* was the habit of masticating each mouthful thirty-two times before swallowing. In other words, he was a pioneer in the propaganda of Fletcherism, for half a century before Fletcher. If Fletcherism does nothing else, it does make for the consumption of the least possible amount of food. How much were Gladstone's liberalism and abstemiousness connected ?

An American politician who looked like Bismarck, behaved like him, and ate like him was Boies Penrose, of Philadelphia. If portraits of the two men are compared, the most remarkable resemblance becomes apparent : which means that they both had the same underlying endocrine constitution. They were the same types of personality, functioning in different social environments.

Penrose was six feet four in height and always weighed much more than two hundred pounds. In his dealings with people he pursued Bismarck's ' blood-and-iron ' policy in a much less diplomatic way, and of course on a much smaller scale. This was simply because he had, as his supposed master, not an Emperor, but the sovereign people of the State of Pennsylvania whom he despised about as much as Bismarck did Kaiser Wilhelm the Second. He was a Harvard graduate, and possessed a family pedigree which ensured him against any complexes of inferiority. All his adult life he controlled the Republican Party in his State by outright bullying and straightforward domineering.

In Walter Davenport's recently published life of Penrose, entitled *Power and Glory*, some of the details are presented of his eating and drinking habits. For breakfast he was accustomed to have a dozen fried eggs, a half-inch-thick slice of ham, a dozen hard rolls, and a quart of coffee. A waiter in Atlantic City tells a story of how at one meal Penrose put away : a dozen raw oysters, chicken broth, a turtle stew, two wild ducks, mashed potatoes, haricot beans, macaroni asparagus, cabbage salad and stewed corn, a whole mince pie, washed down with a quart of coffee and a bottle of

sauterne, a quart of champagne and several cognacs. At a party lasting two days and nights, given in honour of the coming election of Matt Quay to the United States Senate, he consumed two stuffed turkeys and six quarts of whisky. The demand of his tissues for food was truly gargantuan.

The Ideas of Mahatma Gandhi

Of present-day leaders, Mahatma Gandhi alone has put himself on record concerning his diet. As a result of his personal experiments upon himself, he has found that it is absolutely necessary to regulate what enters his stomach in order to control what enters his brain. To maintain what he considers a spiritual state of mind, he limits himself to goat's milk and dried fruit, such as dates. Interestingly enough, this is a perfect diet for a man of Gandhi's type. The fruit supplements the deficiencies of the goat's milk, which has a fat content higher than that of cow's milk and so supplies more calories volume for volume. It is not a diet calculated to make for a high specific dynamic action and so would tend to produce a state of bodymind which makes for restfulness rather than restlessness. For one who seeks a life of meditation rather than of energy and action, such a diet is ideal.

In his book, *My Experiments with Truth,* Gandhi has described how he has experimented with diet. As an individual so different from Bismarck and Penrose in type and physique, manner of living and ideals of attainment, his ideas demand respectful attention. Whatever may be the outcome of his campaign to free India, he will be regarded as one of the outstanding figures of our dangerous and precarious age.

Gandhi attempted by his experiments upon himself to rule his mind by what was introduced into his body (or to recognize the principle of bodymind). He began these experiments in 1906. Particularly was he interested in the effect of food on what he calls carnal passion, more plainly known as sexual lust. For he had decided that in order to become a Brahmachari (one who has taken the vow of chastity in order to devote himself to a life of devotion to his fellowmen), it was necessary to curb his food intake, to make it as simple and uncooked as possible, and completely free of the usual spices and condiments of the Indian cuisine.

After six years of experimentation, he became convinced that for his purpose the effective diet was one consisting only of nuts and fruits, fresh where possible. He gave up milk and cereals entirely for the time being. To the fruit and nut diet he added days of fasting when he took nothing but water. What he describes as complete 'immunity to passion' was attained on this régime. But he found that he had to go back to milk in order to have enough muscle-building—that is protein—food in his meals. Upon the addition of the milk to the fruit and nut diet, a certain amount of sexual excitability and interest returned. He therefore classifies milk as a sex stimulant and writes, 'I have not the least doubt that milk diet makes the Brahmacharya [chastity] vow difficult to observe.' He writes that he is convinced that the character of his thoughts and desires varied definitely with the nature of his food.

As regards what other observers say concerning the effect of his mode of life upon his bodymind, the following quotation from an interview with the Reverend John Haynes Holmes, an intimate friend, is worth quoting:

Mr. Holmes asked, 'Where do people get the idea that he is ugly? Why do they describe him as a dwarf and a "little monkey of a man"?

'It is true that his limbs and body are emaciated, but his frame is large and his stature erect and tall,' Mr. Holmes said. 'It is true that his individual features are not lovely. But the light of his eyes, the beauty of his smile, the atmosphere of his presence, are sublime. What impresses one is not the physical appearance, but the spiritual radiance of this man.

'You think at once of his simplicity, his sincerity, his purity. He approached you with all the naturalness and unheeding spontaneity of a little child. There is not an atom of self-consciousness in Gandhi—in spite of all his greatness, and the adulation which has been showered upon him, he has no pose, no pretentiousness, no pride. Yet he has the dignity of a king. He speaks as one having authority. And he commands by the sheer power of the spirit.

'His intellectual capacity is extraordinary. Here I was surprised, for one does not necessarily nor easily associate mental power with sainthood. The Mahatma, as his name implies, is a great soul, but he is also a great intellect. I have never seen such clarity of mind, such precision of thought. His knowledge of Indian and British affairs is exhaustive; his resources of policy and principle exhausting to those who must deal with him. He

is easily a match for the best minds in English. Do not be deceived—Gandhi is a statesman of the first order as well as a saint of the most exalted rank.'

History and historians of character, from Plutarch to Strachey, have been too neglectful of the dietetic biography of their subjects. They tell us least or nothing about what the celebrated characters of their histories liked to eat and what they disliked to eat. In our time, the concentration upon sex has so monopolized attention as to exclude interest in what is just as important a matter of interest. Knowledge of the food habits of important personages should be regarded as at least as significant as the understanding of their sex life. More research should be made into the records left by doctors of their famous patients in other ages.

It may be taken for granted that the food habits of leaders differ as much as those of their followers. It is fundamentally a matter of the type of metabolism. So there are as many types of leaders as there are kinds of causes which they lead. But the kind of cause they lead is correlated with the constitution of their ductless glands and so with what they feed themselves. Intelligence seems to play a minor role in the variety of food selected. It is much more a matter of conscious or unconscious realization of the needs of the particular bodymind.

The Chemical Qualifications of Executives

Who should rule ? Bernard Shaw once wrote, in his *Man and Superman,* that Government presents only one problem : the discovery of a trustworthy anthropometric method. In other words, how to measure men. For common sense would lead even the most rabid of democrats to admit that the ablest, those best fitted to deal with the problems of life, should rule the vast populations of modern states composed of idiots, morons, and dull normals. For a time, the psychologists contended that they had the secret of government in their I.Q.—their intelligence quotient—a rating by which men could be placed in their true position among the social hierarchy. But it takes more than intelligence to live, and it demands more than a high I.Q. to become a successful executive. It is the other, the dynamic personality deter-

minants, outside of intelligence, that really make and unmake leaders.

Physique, temperament, character—physique, chemique, psychique—these are the fundamentals upon which the psychology of the ruler must be built. The whole psychic superstructure of the leader is erected upon the chemical foundations constructed by the functioning of his endocrine glands. For it is their action which manifests itself in those characteristics of the bodily carriage and facial lines, of the emotions and the voice, of general behaviour and manner, which stamps the executive personality. It follows that an accurate and complete analysis of how the ductless glands are working in any school-child, for instance, could be used as a basis of prediction regarding his capacity for leadership. And it may be said that an adolescent will turn out to be as good an executive as his hormones permit him to be. And a man remains an effective leader only as long as his body-mind chemistry stays supernormal.

The general principle at work is the superior activity of the pituitary, the adrenals, the thyroid, and the sex glands. Their various proportions of superiority, different combinations and permutations, determine the kind and direction of leadership in any social *milieu*. Napoleon needed the French Revolution and the eighteenth-century atmosphere of his time to make possible the expression of his glandular formula in his historic career. But in the thirteenth century he would perhaps have become a Pope or a Crusader, and in the twentieth he would have made an unscrupulous world-famous business organizer or stock manipulator.

Popular opinion or acclaim, in choosing leaders—say, the president of a country—often hits upon the right person because an unconscious appraisal of the desirable glandular qualities is made. Thus may be explained the almost miraculously appropriate selection of a Lincoln or a Washington. The shrewdest men in judging others take account of their glandular constitution when they measure the significance of their more superficial as well as their deeper characteristics. With developing knowledge of the internal secretions, the selection of leaders, commandants, executives, and presidents will be taken out of the field of successful intuitive guesswork and rule of thumb, to be replaced by the scientific charting of the endocrine equipment for the particular job in

view. That is how the problem of the man-for-the-position will ultimately be solved by endocrinological methods supplemented by psychological tests.

But always it should be remembered that endocrine nutrition or malnutrition, in a child or man once equipped to be a leader, will determine whether he will continue to be. In other words, the best of endocrines may degenerate. That is why it behoves nations as well as individuals to watch the qualitative and quantitative composition of their foods, and particularly of those foods which contribute importantly to the ductless glands and influence their functioning in one way or another. For there can be no doubt that the emergence and decadences of peoples have been affected by the character of their food supply over a series of generations.

The Insurance of National Leadership

One of the mysteries of the history of civilization is the movement of energy from one national group to another. The rise and fall of nations and empires follow a curve of intensity of energy production and diffusion. The leadership of one people and then of another sets the pace for the forward movement of culture and conquest. Energy flares for one generation, two generations, three generations, or four generations, the hundred years or so of dominance in the affairs of the world. Thus empire passes from Egypt to Assyria, Babylonia, Persia, Greece, Rome, Arabia, Spain, England, France, Germany, and America. In each, during a certain epoch, the people seem to become charged with a dynamic energy which produces action and expansion on a tremendous scale. Then a disease of exhaustion follows, the leaders become effete and their followers with them.

Various explanations have been advanced for this focal movement of energy. Certainly, no single reason can explain it. Sometimes an infectious idea alone, like Mohammed's contagion of Islam, may serve as a fairly satisfactory explanation. A number of theories have been offered. But with the development of modern knowledge, it has become apparent that food undoubtedly played a determining role in the fate of nations. Who can say what caused the curious resurgence of creative energy in the England of the sixteenth

century, the century of Shakespeare? How effective was the introduction of new foods and spices from the East and the West?

It is the task of research to analyse the food habits of the various great peoples of the past. It is possible to draw a chart showing the various excesses and deficiencies of the historic nations significant in the life-history of the great states. It should always be realized that the important effects of foods upon the ductless glands are the result, not of a single meal, but of dietary tendencies over a period of years and generations.

In the United States, for example, one of the developments of the twentieth century is the prevalence of obesity on a scale that has attracted the attention of all observers. In the days of the Colonies, and in the early days of the Republic, food was as plentiful as air. After the American Civil War, the new nation, running itself as a democracy, aroused the curiosity of many Europeans who visited the country to inspect its wonders, just as many Englishmen to-day go to Russia to see the newest of experiments in national organization. Their comments were quite the contrary of those who visit Russia to-day and emphasize the paucity and inadequacy of the food. What they remarked on was the tremendous supply of victuals of every sort which every one gorged at every meal. Yet contemporary descriptions of the inhabitants harp upon the fact that they were so lean and wiry as to provoke comment.

Americans of our own times, though, are pictured by foreign observers as fattened and softened individuals, who seem to belong to another race. Indeed, the contrast between the American of the year 1830 and his descendants of the year 1930 have found expression in the cartoons and caricatures of the two periods. These type figures of the contemporary artists reflect an image in the unconscious which is a sort of composite photograph of their perceptions. All one has to do is to compare the lanky, straggling figure of Yankee Doodle drawn by Darley with the spreading pot-bellied Uncle Sam of Max Beerbohm to realize the difference. And the latter is distinctly a late development. For a comparison of the type cartoons of the intervening decades—when Yankee Doodle became Brother Jonathan, and Brother Jonathan became Uncle Sam—exhibits the same difference.

Something has happened in the last thirty years to the average metabolism of America.

Now, what have been the causes of this change in metabolism, a change from a higher rate to a lower rate, for it is such a change that is accompanied by a deposition of fat and a lessening of that energy, activity, and ingenuity which make for world leadership?

Something may be said for the view that the removal of the chief stimulus to activity, the exploration and exploitation of a pioneer country, has been responsible. But more can be said for the effect of a change in the food habits of the country. This change has been the gradual switching from a menu of fresh food, out of the field, garden, or forest, to a diet of 'refined' and 'denatured' foods. In consequence, the diet of the people has become unbalanced and deficient in various respects, with repercussions of insufficient nutrition of the endocrine glands and a general lowering of metabolism.

This change in diet has occurred in all the different food elements: in the protein intake, in the mineral intake, in the vitamin supply, in the fat intake, and in the sugar and starch consumption. In the tremendously increased use of white refined cane sugar, sucrose, ordinary table sugar, as a food, we have a perfect example of what has been happening all along the line. Until the development of industrial chemistry on a large scale in the second half of the nineteenth century sugar was as expensive a luxury as caviare. Queen Elizabeth used it as a condiment only. From an ultra-luxury it has become a common necessity.

In her history of sugar, Ellen Ellis has pointed out that in the fourteenth and fifteenth centuries, sugar sold in England at from one to two shillings a pound. At the same time, money could buy then about twenty times what it can buy in our time. In other words, a pound of sugar cost from one to two pounds sterling. In 1870, sugar sold at two pounds ten shillings a hundred pounds and in the year 1913 at less than twenty shillings a hundred pounds. Nowadays sugar sells at about twenty shillings a hundred pounds.

Corresponding to this drop in the price of sugar has been an increase in its popularity as a food. A century ago, for instance, the average consumption of sugar in the United States was about nine pounds a year per person. In 1924, it was one hundred and ten pounds per person per year, making

over two pounds per week. People now eat almost as much sugar in a month as they formerly consumed in a year.

Now, sugar is solely a carbon food and a one-hundred-per-cent calorie-producing food. According to Mendel, if the *per capita* consumption of sugar in 1823 in the United States is calculated as calories, the sugar equivalent would amount to forty-four calories a day. A hundred years later, the calorie value of the daily combustion of sugar per individual had increased more than ten times and is equivalent in fact to 547 calories. If one takes the average calorie requirement as about 2,500, this means that about a fifth of the total daily heat production is provided by sugar.

Meanwhile, sugar has become more and more refined. More and more of the associated constituents in the cane syrup have been removed. The brown sugar was finally turned into the perfectly pure white sugar, completely deprived of its concomitant minerals and vitamins. In short, the augmented employment of refined sugar has facilitated the occurrence of the mineral and vitamin deficiencies which lead to inadequate or imbalanced functioning of the endocrine glands.

An explanation for the general spread of fat in America thus becomes apparent. The ingestion of so much sugar and other artificially manipulated foods has furnished an excess of calories to a bodymind made incapable of properly disposing of them, because its endocrine glands have been starved and maltreated.

The American versus the Russian Diet

Now, while America may be cited as an example of a people destroying its health and losing its capacity for leadership by overeating the wrong foods, Russia may be named as the contemporary nation which is inviting defeat of its projects through neglect of the dietary needs of its citizens by underfeeding. America and Russia, the outstanding countries of the world to-day in the opposition of their ideas, methods, cultures, and aims for the organization of human society, both lay themselves open to the insidious degeneration of imbalanced feeding and consequently defective endocrine glands.

There is no excuse at all for the Capitalist America, with its tremendously exploited resources. It has the scientific

knowledge and the scientific workers who are aware of the facts, but are not making themselves heard. Soviet Russia has concentrated so closely upon the conversion of its workers to the ideals of Lenin that it has become as neglectful of the chemical care of their bodyminds as the hair-shirt-wearing residents of medieval monasteries.

As the following copies of the menus of the average Russian worker (as contrasted with the favoured specialist or skilled employee) show, his food is lacking in minerals, proteins, and vitamins. I am obliged for these lists to a recent visitor to Russia. They prove that no matter how hard the Russians may strive to realize their Five-Year Plan, or their Ten-Year Plan, they will fail to produce a people fit to cope with the trials and tribulations history will confer upon it during this twentieth century.

Daily Menu of Industrial Worker in I A Category

(on more than one hundred roubles a month wages)

Breakfast

Tea from samovar
Egg boiled in steam on top of samovar (rarely)
Black or white bread
Sugar or jam

Dinner

Cabbage soup, made with meat (once or twice a week, margarine remainder)
Black bread
Boiled potatoes, or cooked cereal (kasha)
Cutleti (ground meat cakes) once or twice a week, *or* fresh fish, *or* cottage cheese cakes (fried)
Salad (in summer), lettuce, cucumbers, tomatoes, served with smetaba (sour cream), now scarce
Compote (stewed mixed dried fruits, of poor quality) or strawberries or other fresh fruit in season

Evening meal

Tea from samovar
White bread, sometimes with butter, jam
Bologna or cheese

Daily Menu of Worker in I B Category

(or a worker earning less than one hundred roubles a month)

Breakfast

Tea with black bread

Dinner
Cabbage soup, usually with margarine
Black bread
Boiled potatoes, kasha or macaroni
Ground meat cakes or fresh fish once a week
Cucumbers or pickles in season

Evening meal
Tea with sugar or jam
Black bread with bologna or dried fish

The industrial worker may eat dinner at noon in the factory dining-room, or in a *factory kitchen* (large-scale dining-rooms serving several factories in the neighbourhood)

Factory Dinner
Cabbage soup (usually with margarine or fish)
Meat cakes or boiled fish once or twice a week
Boiled macaroni, potatoes or kasha
On meatless days, kasha made of millet or grits and served with stewed fruit, is the second course
Tea, bought with extra coupon, in buffet, as well as other specialities, like cookies, bread with bologna or cheese, candy, all rather expensive

Daily Menu of Employee in Second Category

(whose income does not permit supplementing rations in open market)

Breakfast and *dinner* similar to I B, or poor worker
Lunch in buffet room at place of work
Soup with black bread
Boiled potatoes with margarine
Ragout of beef with black kasha
Fish cakes with potatoes
Tea, sometimes without sugar

These factory dining-rooms vary in quality according to the prestige of the organization. The menu varies considerably according to supplies available, which are most erratic. Sometimes they will get in a whole hog or calf and have pork or veal in every conceivable form for several days, then no meat for a time. The same is true of the fresh fruits and vegetables. The whole ration system operates in this way, distribution being on a mass scale. For instance, the monthly allowance of butter is received in one piece, and, without ice, must be eaten or otherwise disposed of quickly.

Children receive a litre of milk every third day and it must be boiled immediately.

The menu of the factory cited above is that of a large publishing house, publishing several periodicals, and serving, of course, all persons working there, from scrubwoman to editor.

Daily Menu of High-Salaried Employee, Responsible Worker or Specialist

(with special closed store, or able to buy in open market)

Breakfast

Tea or cocoa
White bread and butter with ham
Boiled egg or smoked fish, or ham, or caviare

Dinner

Soup, usually beef, sometimes chicken, with carrots and other vegetables
Roast beef, or pork, or chicken, or cottage cheese cakes served with sour cream
Boiled potatoes or rice
Salad of fresh vegetables with sour cream
Fresh or dried fruit or bleenchiki (little pancakes served with jam, honey or sour cream)

Evening meal

Tea from samovar
White bread and butter
Ham, cheese, or caviare
Cakes or French pastries or bleenchiki

The declassed, who have no food cards at all and earn too little money to buy in the open market, appear to have nothing except black bread, tea, and cabbage, occasionally mushrooms, potatoes, or carrots. The declassed living in the same apartment with workers are often permitted to share the latter's bread and other rations. Some of the women find a profession in standing in a queue for the other women of an apartment, receiving as their pay 10 per cent of all food purchased. Old people on pensions and dogs registered for military service have food cards, of a lower order than I A and I B.

These two competitors for the leadership of the culture and civilization that will dominate the next epoch in human history must put their houses in order from the chemical

foundations up—the scientific feeding of their citizenry. From the very first year of childhood, through adolescence to adult manhood and womanhood, the State should maintain as jealous an eye upon what enters the stomach of its inhabitants as upon what it permits to be introduced into their minds. Surely it should apply as strict standards for the needs of their physique as it employs for those who would pass its portals to become fresh additions to its population.

Jointly, education and supervision could accomplish the task of establishing and making effective a *physiological conscience* concerning the most fundamental of the daily acts by which man assists or injures the sanity of his bodymind. It is with the developing knowledge of the *food hygiene* of the endocrine glands that we are particularly concerned. The development of special diets to protect these hormone-producing organs against injury, depletion, exhaustion, and disease is the most important task of those who plan and manage diets either for themselves or others. The intimate relations between nutrition and the ductless glands are now being worked out in detail. The practical application of them, which has already yielded the most valuable results, depends upon a general recognition of how the different foods affect the different endocrine glands specifically, and so assist in making the various differences of personality which distinguish the types of human beings who make human society ‘ all sorts and conditions of men ’.

CHAPTER IV

THE STOKING OF THE ENDOCRINE GLANDS

THERE are a number of fallacies current concerning the fundamentals of diet and the chemicals of food passed into the bodymind. One that has done most harm is the idea that eating is merely the stoking of a heat apparatus, comparable to the introduction of coal into a furnace or gasoline into an internal-combustion machine. Of course, the quality of the coal or gasoline is supposed to be given some consideration. But essentially, food was regarded and still is regarded as mostly a matter of the 'calories'.

The discovery of the vitamins and the 'little things' of diet, and the consequent dethronement of calories, has led to some slight revision of that attitude. Still, even now, fairly well-informed people take their meals on the assumption that, as long as they are full of calories and vitamins, they are being adequately nourished.

Now, food affects character and personality in three ways. First, food acts upon the blood, changing its chemical composition by the direct addition or subtraction of various constituents, such as acids or salts. Second, food influences the ductless or endocrine glands, stimulating them to more secretion or depressing them to less secretion of their hormones. Third, foods provide the raw materials for the endocrine glands, as well as for the brain and the rest of the nervous system; the latter may also be affected directly through the blood and indirectly through the ductless glands. There is, therefore, an interlocking chain of effects. For example, iodine-containing foods pass into the blood and influence the thyroid, which acts upon the brain to make it more or less sensitive to stimuli.

In their turn, the ductless glands may modify the blood—for example, insulin lowers the sugar content of the blood. The endocrine glands may stir the brain to its greatest

activity. The action of thyroxin in arousing the cretin from his intellectual torpidity has been mentioned. A not so obvious effect is the action of adrenalin in raising the temperature of the brain, making it keener and more alert for battle.

Conversely, the brain influences the internal secretions by way of the sympathetic nervous system as well as by means of the metabolic centres hidden within its depths. These regulate the emotional effects of experiences upon water, salt, sugar, fat, and protein metabolism. Thus an emotion experienced, a sight of danger, an odour of the past, an association with a once disagreeable quarter of an hour, will cause impulses to travel along the sympathetic nervous system to various glands. Discharging more or less of their material into the blood, they liberate a sequence of chemical events most important for the moods, attitudes, and reactions of character.

Blood and Character

In approaching the practical side of the problem of controlling the development of character and personality in a child—or in attempting to modify character reactions, as in the treatment of neurotics—it becomes imperative to analyse them from the chemical viewpoint. Such an approach looks upon each individual as an intricate chemical system of machines. The chemical reactions of the complex system generate and regenerate energies of various sorts. From the chemical point of view, man is a dynamic arrangement of materials and forces out of which constantly emerge the new properties and possibilities of his behaviour and organization.

The ideal we set ourselves, then, is to discover just how his food, the chemical substances of his daily meals, is transforming the blood, the endocrine glands, and the brain of man. The tragedy and comedy of his life take place in his internal laboratories. If all is not going there according to his heart's desire, what measures may be taken to change the course of unhappy events in the bodymind toward a more happy ending?

The study of the chemistry of the blood by modern methods of quantitative chemical analysis of its constituents has made remarkable advances possible. Using relatively the smallest amount of blood obtainable, procedures are available for the

exact determination of the amount of water, salts, sodium, potassium, calcium and magnesium, iron and phosphate, sugar, fats, fatty acids, proteins, cholesterol and lecithans, uric acid, urea, creatin, amino-acids, and so on. Blood chemistry of to-day is indeed a marvel of human ingenuity in the refinement of technique that has been worked out to deal with the minute quantities of the various substances present in the blood. For most of them, the concentrations are statable only in terms of milligrams, or fractions of 1 per cent.

By utilizing standard basal conditions, a study of the chemistry of the blood will supply profound insight into the individual peculiarities and needs of diet. One may infer how the various foods are being handled by the tissues. That is, how quickly they are being burned or transformed, and how completely. And finally, how much is accumulating to become the ‘ clinkers ’ or ‘ slag ’ of the cells. These form the debris which make for disease.

A truly scientific diet may thus be constructed to suit the capacities of the individual, preventing any strain upon his metabolic machinery. By eradicating the effects upon the vital organs of wrong or imbalanced food in their earlier functional stages, organic disease may be prevented. And even organic conditions brought about by food deficiencies may be greatly benefited.

Preventive dietetics, one of the most important of the unexploited branches of modern preventive medicine, is coming into being as a result of the knowledge now developing in the field of nutrition. But such knowledge will prove effective only when it is combined with a study of the unique peculiarities, limitations, and potentialities, characterizing the individual organism which is to be fed.

Now the relation of food to blood and character is directly and inextricably connected with the functioning of the endocrine glands. That is one of the most important laws discovered in the history of modern science.

The Endocrine Glands Regulate the Composition of the Blood

Food deficiencies or excesses, dietary imbalances, reflect themselves readily in the composition of the blood. The chemical analysis of the blood, however, even under basal conditions, provides only a snapshot, as it were, of what is going on in the tissues. Such a picture is valuable, in-

valuable, for the construction of an adequate optimal diet. Yet, unless one draws into the picture the endocrine (or ductless) glands, no real progress can be made in understanding the effects of food and its mirror, the blood, upon character and personality.

These glands, the thyroid gland in the neck, and the parathyroids which are its neighbours in the neck, and pituitary gland in the head, and its neighbour, the pineal, the thymus gland in the chest above the heart, the adrenals in the abdomen above the kidneys, the sex glands, have come more and more to dominate the picture in all modern studies of the physiology and the psychology of the individual. The student of diet is interested in all these ductless glands, because they affect the history and adventures of every molecule and atom of food from the very moment of their entry into the body. To begin with, the endocrine glands control the organs of digestion because their hormones act directly upon the stomach, the duodenum, and the rest of the intestines, the liver and the pancreas, and also the colon. The composition of the gastric juice, of the duodenal and pancreatic juices, the rhythms of the small and large intestines, are all regulated by them. Besides these, there is the action of the sympathetic nervous system which is itself controlled by the endocrine glands. A wrong diet may derange both—the adequate production of the hormones (the substances manufactured by these glands) and the functioning of the nervous system.

Most intimately related are food and the intestinal tract. A number of observers have called attention to the frequency of intestinal derangement as a result of defective diets. The glands of the upper intestine elaborate the hormone, secretin, which stimulates another gland, the pancreas, to pour out its digestive juices into the alimentary canal. These are most important for normal digestion and good health. The upper intestine also elaborates another hormone which is mobilized when sugar enters the duodenum. This hormone goes to the pancreas and calls out the insulin reserves to assist in the burning of sugar.

Secretin is mobilized by the stimulating action of hydrochloric acid, a normal constituent of gastric juice. When food gets mixed with gastric juice, it is expelled from the stomach into the intestines. There the products of digestion

excite the cells to send their secretion to the pancreas. Pancreatic juice is then mobilized, hurries through the pancreatic duct, then into the common bile duct, where it becomes mixed with the bile which comes from the gall bladder.

The upper intestine also makes a hormone that contracts the gall bladder. It is called 'cystokinin', and empties the gall bladder in which bile is stored from the liver.

Bile mixed with pancreatic juice make the most efficient digestive mixture. *Food and hormones become intimately involved from the moment of the entry of food into the stomach and intestines. The endocrine glands are dominant in the whole process of digestion, as well as of metabolism.*

Food and Vitamins—Raw Materials for the Endocrine Glands

But food is important for the endocrine glands from an even more fundamental point of view. The endocrine glands are chemical factories. Their products of manufacture are the hormones which pass into the blood, the lymph, and the tissues. There they act as catalysts, promoters of chemical reactions, to exert their effort of speeding or slowing all the functions. They are thus the directors and thereby the dictators of every activity of the bodymind. To make their hormones, in the right amount, at the right time, the endocrine glands must first of all be supplied with the raw materials out of which their secretions can be manufactured. These raw materials are present in food.

Compared with the proteins, the hormones are relatively simple substances, of a much lower molecular weight and complexity. The chemical composition of several, which have been either crystallized or synthesized or both, is known. They belong either to the class of alkaloids, resembling substances like quinine or atropine, or to the class of lipins, like the fatty acids.

The hormones themselves must needs have chemical precursors in the diet. Of all the food substances which are important for the functioning of the vital organs, none is more important than the vitamins. It has been shown that the substances of the vitamins are absolutely essential to the normal growth and development of the young of any species, including the human. The attainment of adult size, the normal sexual evolution including sexual instincts, reproductive capacity, ability to secrete milk and to suckle the

new-born, the maternal instinct, fertility, and the handing-on of perfect germ plasm for three or more generations, are all involved. Other characteristics like energy, resistance to infections, and the maintenance of a normal nervous system are also affected.

But now, if one looks upon a list of the vital functions regulated by the glands of internal secretion, one sees that the two lists are practically identical. For it is now universally admitted that the endocrines control growth and development so that no specimen of any of the higher species can arrive at adult maturity without enough of their products. And all the complications that sex introduces into the life of any individual or animal—puberty, coitus, pregnancy, parturition, lactation, parenthood, the sexual, maternal, and parental instincts, emotions and excitements, can be experimentally controlled by the manipulation of these same glands.

It is an obvious advance in thought, on comparing the two lists, to conclude that the vitamins act through the endocrines. They function either by furnishing themselves as the crude stuff out of which the hormones are elaborated or by acting as catalysts (persuasive messengers) to stimulate or depress their activity. At any rate, the similarity is so striking that the name 'food hormones' has been suggested for the vitamins.

If the relationship between the vitamins and the endocrines is so intimate, one way of controlling the functioning of the endocrines becomes apparent. This way is along the direction of regulating the variety and quantity of the vitamin intake. In conditions of character and personality defect or abnormality, where the status of one or the other of the endocrine glands has to be investigated, the nature of the food supply should be considered most seriously. It may be a possible factor in the production of the disturbance of the glands of internal secretion. And in the treatment of such a condition, the prescription of a diet calculated to affect the endocrine gland in question becomes a therapeutic necessity.

That there is a definite relation between the vitamins and the nervous system is proved by the occurrence of disturbances of the nervous system in such vitamin deficiencies as beri-beri, scurvy, pellagra, and rickets. These effects are of two kinds. First, there is a direct effect of the vitamins

involved upon the functioning of the brain as expressed in character and personality. And then there is an influence of the vitamins upon the endocrine glands, an indirect relation of vitamin deficiencies to deviations of character and peculiarities of personality. These conceptions have been found most useful in clinical situations presenting problems of the intellectual or emotional life of patients. The correction of dietary defects, especially in the vitamin content, has been of invaluable assistance in such instances.

A host of researches, experimental observations in animals, and studies of human beings now demonstrate that whatever affects the endocrine glands, deleteriously or favourably, affects character and personality. In 1920 the present writer assembled the evidence for this law and its underlying principles and conceptions, in a book entitled *The Glands Regulating Personality*. Since then, hundreds of articles and books have been published containing data which can only be interpreted as supportive and corroboratory of the conceptions presented in that book. There can be no doubt in any unprejudiced mind, no matter how sceptical or critical, of the validity of this great generalization, first presented ten years ago. The glands of internal secretion make and regulate the types of human nature, their class characteristics and individual deviations and variations.

Vitamin B Necessary for the Thymus

Now, the first gland to be considered from this viewpoint, the thymus, is one whose condition has been often recorded in chronic diseases and misfortunes. The thymus gland, commonly known as the 'sweetbread' of primeval carnivorous English, is situated in the chest directly above the heart. The word 'thymus' (thumos) in Greek means heart, and it also means courage, and it is thought it was so named because it was looked upon as the 'centre of courage'. And as the heart is usually the first organ to be inspected in an autopsy, its neighbour, the thymus gland, is regularly reported upon also.

The thymus is a gland which is most prominent during childhood. But this does not mean that its secretion cells do not persist throughout life. Its influence wanes during puberty and adolescence. But it continues to function throughout the period of maturity, even to senescence.

Everything points to a close relation between the thymus, nutrition, and growth. It is influenced by bodyweight and growth with great facility. It seems to act as a storage organ, affording a certain amount of protection against the deleterious effects of a lack of food.

As long ago as 1845, Simon, an English physiologist, called the thymus gland ' the barometer of nutrition ', in his book, *A Physiological Essay on the Thymus Gland*. Summarizing his conclusions, he wrote :

> I think it extremely probable that the thymus may within a few days, if not hours, vary remarkably in the same individual, according to the immediate state of general nutrition. Its state seems to be, *cæteris paribus*, if I may venture to use the phrase, a barometer of nutrition and a very delicate one.

The thymus may become smaller or completely atrophy as a reaction to exhaustion, excessive activity, infection, and malnutrition. This type of shrinkage, Hammar, foremost of its investigators, has designated ' accidental involution ', to contrast it with the normal or natural ' age involution '. The latter begins at puberty and is completed at the attainment of maturity.

The changes due to malnutrition are most interesting. Starvation causes a sharp loss of weight of the thymus. Together with fat, it seems to constitute, in the child especially, a source of reserve material for continued existence and growth in spite of a discontinuance of the outside supply of food. After a month of malnutrition, the thymus may shrink to one-fiftieth of its original size.

The thymus is made up of two kinds of cells : (1) round lymph cells which are emigrants to its territory, and (2) supporting these, a basic network of original thymic, also called reticular, cells. The true thymic cells may form giant conglomerations known as ' Hassall's corpuscles '. The cells first and most affected by malnutrition are the lymph cells. Later the thymic cells and their products, the Hassall's corpuscles, also degenerate. If the malnutrition is continued too long, no regeneration is possible even after the restitution of proper feeding. But ordinary conditions, proper feeding, will eventuate in a return of the gland to its usual appearance, structure, and weight, with a return of lymph cells.

In 1923, Lefholz published a carefully controlled study of

the effects of diets varying in calorie value and in relative amounts of fat, sugar, and protein upon the growth of lymph cells in kittens. He reported that the thymus was not consistently influenced by variations of fat, sugar, or protein. He did find that on a high calorie diet, with high protein or high sugar, the *tonsils became enlarged* to twice the size of the normal, while a high fat diet made them three times the size of the normal. This establishes a sharp distinction in reaction between the thymus and the tonsils. The two organs have been often compared as they resemble one another in their content of lymph cells.

All observers agree that the thymus does not change appreciably in scurvy, which rules out Vitamin C as an important factor in studying the relation of the thymus to the diet. The relation of the thymus to malnutrition is best explained by the work of Cramer and his associates. They have related it to Vitamin B and have shown that the growth substance in malnutrition to which the thymus reacts is that vitamin.

In all animals, pigeons, chickens, mice, rats, and monkeys, the disease beri-beri, due to deficiency of Vitamin B, is accompanied by a profound atrophy of the thymus gland. The work of Cramer and his colleagues has thrown a great deal of light on these reactions of the thymus to vitamin underfeeding.

Nowadays no one accepts an underfeeding reaction as due to a lack of calories only or of non-specific elements. The attempt is made always to trace it to some definite deficiency of one or another of the food essentials. It may turn out to be one of the proteins, including the different amino-acids, or one of the various sugars and starches, or one of the fats, or one of the different salts of lime, phosphorus, iron, and so on, and last, but by no means least, one of the different vitamins. Of these last at least seven are definitely known, Vitamins A, B, C, D, E, F, and G. There are others which have not as yet been named. Cramer has analysed the shrinkage of the thymus following underfeeding and definitely shown that it is due to Vitamin B starvation. This implicates the thymus in Vitamin B metabolism.

Cramer found that when an animal was kept on a diet complete in every other respect, but lacking in Vitamin B, the growth of the animal stopped. It lost weight, developed a

subnormal temperature, and finally died completely emaciated. *Post mortem* examination showed an almost complete disappearance of the lymph tissue of the body, most marked in the thymus, which was hardly visible. The lymph cells of the blood diminished greatly at the same time.

Lymph cells have been called ' police ' cells, because they protect human beings (especially children) against infection. Vitamin B is necessary to the formation of lymph cells. Lymph cells are necessary for the proper growth, nutrition, and maintenance of the bodymind, as well as resistance to infection.

Vitamin B acts through the lymph cells. And there is an important interdependency between Vitamin B, lymph cells, and the internal secretion of the thymus. When a Vitamin B starved animal is fed large quantities of Vitamin B, there occurs a complete restoration of good health. There is a return of a normal number of lymph cells in the blood and a restitution of the thymus, which may for a time reach a size beyond that regarded as normal.

The thymus may also be made to shrink by X-ray treatment of it. This was first studied by Heinke, and confirmed by a number of other observers. There is this difference between the atrophy of malnutrition and the X-ray effect : after a sufficiently large dose of the X-rays, there occurs not an emigration of the lymph cells from the thymus, but a destruction of them. The true thymic or reticular cells are not so much affected by the rays, and in fact incorporate and digest the dying lymph cells. In the course of a few hours, the thymus may thus be transformed into an organ consisting almost wholly of the true thymic cells.

After a time, however, new lymph cells come in from the blood vessels, as if attracted by some stimulus provided by the thymic cells. Ultimately, the original glandular structure is reformed, with its predominantly lymph cell exterior and its predominantly thymic cell interior. Yet the total size of the organ, as demonstrable by X-ray photographs, may remain permanently reduced.

X-ray or radium treatment of an animal will cause an effect upon the lymph cells within an hour. There is a definite diminution in the number of such cells circulating in the blood. This diminution may be appreciable an hour after exposure to an amount of radiation insufficient to be detected

photographically. In other words, the biologic test is more delicate than the physical.

Not only may none of the lymph cells be present in the blood, but an examination of the thymus, spleen, and other lymphatic tissues may show a complete absence of lymph cells. If small doses of radiation are repeated, the same effects appear as those seen in Vitamin B starvation. Rapidly the animal loses weight, the temperature becomes subnormal, which means a subnormal metabolism. The testes, as well as the thymus, atrophy and death supervenes.

All the evidence, then, is great that there is a relation between growth, the lymph cells, Vitamin B, and the thymus. Lymph cells take part in the absorption of food, particularly fat, from the intestines. They seem to be necessary for Vitamin B utilization by the body, while Vitamin B seems to be necessary for their continued existence. The thymic reticular cells in turn seem to be fed by the lymph cells or by some of their contents, supplying certain products necessary for the elaboration of its internal secretion.

In all conditions involving the thymus, special attention must be paid to the Vitamin B content of the diet.

The Feeding of the Adrenal Glands

The adrenal glands, sitting atop each of the kidneys, and each about the size of a man's thumb, are the 'Glands of Combat'. Each adrenal is a double gland, two glands bound together as one. One gland forms the outer portion of the organ, the other gland is the inner portion. The outer portion of each gland—the cortex—is distinct and produces the internal secretions designated as 'intercortin'. The inner portion is named the 'medulla', which manufactures adrenalin.

Now intercortin and adrenalin may be regarded as inventions for the mobilization of all possible advantages of muscle and blood in a struggle. Emotions produce many of the changes in the organism and consciousness that follow injections of adrenalin. The adrenals play a most important part in the profound processes of fight and flight, which underlie the most primitive reactions of behaviour.

The internal secretion of the cortex controls brain growth. It also regulates the development of the sex glands and the maintenance of their normal tone after adolescence. But the most fundamental function of the adrenal cortex is to

regulate the acidity of the bodymind which makes possible the continuance of life. For, if the adrenal glands are removed or destroyed, death ensues in a few days. This comes about because the bodymind is overwhelmed by the acid by-products of its chemistry.

The reaction of the adrenal glands to malnutrition is a striking contrast to the remarkable atrophy of the thymus gland. In response to several kinds of food deficiency, an enlargement of the adrenal glands occurs. Associated with the enlargement are marked structural and chemical changes in both the cortex and medulla.

The reaction of the adrenal glands, of course, varies with each type of food deficiency. Characteristic differences in reaction can be shown to be due to marked deficiencies in the protein, fat, Vitamin A, B, or C intake.

Hexuronic acid has been identified as Vitamin C. Normally, the adrenal cortex contains hexuronic acid. This suggests a direct relation in between Vitamin C and the adrenal cortex.

In the case of deficiency of Vitamin C, which produces scurvy, increase in the size of the adrenals, with variable degrees of congestion, is observed. The weight of the glands is about double that of health. The amount of adrenalin is about one-fourth that of the average healthy gland. In other words, there is a reduction of the adrenalin-producing power of the glands in scurvy, which may amount to 75 per cent.

Under the microscope the cells show degeneration both in the cortex and the medulla, with haemorrhages in the cortex. These changes may be found even when there is exhibited no clinical evidence of scurvy. Depressed or insufficient adrenal function may be the outstanding symptom in individuals suffering from latent scurvy. Also, acute adrenal insufficiency, a syndrome occasionally seen in medical practice, may be due to a defective supply of Vitamin C. Furthermore, if the diet is rich in the energy-providing foods, sugars, and fats, it will not take much of a deficiency of the Vitamin C to bring about the latent scurvy and adrenal insufficiency.

An entirely different sort of reaction occurs with deficiency of Vitamin A or B or both. In deficiency of Vitamin A, there is an *increase* in the amount of adrenalin corresponding to the degree of enlargement of the gland. McCarrison

found that on a diet of Vitamin B-poor rice, there followed an enlargement of the adrenal glands, with a deficiency of adrenalin. This enlargement also followed on a diet of the same rice, even with fresh butter and fresh onions added. The latter diet contained much fat and Vitamin A. But he found that, though the glands enlarged with the latter diet, there was no increase in the amount of adrenalin in the gland, such as occurs when there is a deficiency of Vitamin A, nor was there any decrease such as occurs with Vitamin B deficiency. The excess of A balanced the lack of B.

A lack of Vitamin A results in a storing of adrenalin in the gland, perhaps due to the absence of a mobilizing principle or stimulus. This storage of adrenalin during Vitamin A deficiency is accompanied by an almost complete disappearance of characteristic fatty substances, the lipins or lipoids, from the cortex. The phenomenon proves a definite relationship of co-operation between the cortex and the medulla of the gland.

One of the striking appetite reactions in animals deprived of the cortex or interrenal gland is a marked aversion to fat. It is as if the animals realized their inability to handle the fats properly in metabolism. Even when they are starved, the aversion continues. Their acidosis is increased when such animals are forced to metabolize fats.

That the adrenal glands are also intimately connected with the metabolism of protein is proved by the changes found in the condition labelled 'malnutritional oedema'. After every war, when a population has been malnourished or subjected to a food stringency, such for example as happened in Germany during its blockade and after the armistice, there has been described a peculiar bloating of certain individuals, associated with ill-health. It has been particularly reported in institutions for the insane or the poor. The condition has been variously named 'war oedema', 'famine oedema', 'epidemic dropsy', or 'malnutritional oedema'. As long ago as the Indian famine of 1877, English observers pointed out that 'famine oedema' was caused by food defective in protein.

It has since been proved by a long line of other investigators, the most recent of whom have been Kohman, Epstein, and Peters, that a deficiency of protein in the food is followed by a deficiency of protein in the blood. In time this protein deficiency of the blood causes a retention of water in the

tissues, an oedema. It represents a disturbance of the metabolism of water and protein.

In a disease of the kidneys described as ‘ nephrosis ’, which occurs most commonly among children following infections of the tonsils, there is a similar disturbance of metabolism and a similar oedema. In young animals, with damaged adrenals due to food deficiencies, oedema occurs in 90 per cent. When Vitamin A is supplied in sufficient amount, it takes *less* protein to cure the oedema, as well as to cause the adrenals to return to their healthy state.

The upshot of all the observations upon malnutritional oedema is a phenomenon of protein and Vitamin A deficiency, associated with a disturbance of metabolism in which the adrenals play a central role. A dietary excessively rich in starch assists in the generation of water retention.

In any personality disturbance in which the cortex of the adrenals may be implicated, special attention should be paid to the Vitamin A and Vitamin C content of the diet. As far as defective adrenalin production is concerned, two dietary constituents should be emphasized—Vitamin C and the amino-acid tyrosin. Adrenalin may be derived from the amino-acid tyrosin with relative ease, and it is probable that tyrosin is the mother substance of adrenalin. A diet high in tyrosin containing proteins, as well as in Vitamin C, is indicated in adrenalin insufficiency.

In adrenal cortex deficiency, a fat-poor diet, rich in Vitamin A, with a minimum of adequate protein, has proved of great aid in clinical practice. These must also be considered in affections of the sympathetic nervous system. The sympathetic nerve cells are closely connected, anatomically and functionally, with the adrenal glands, and with the emotional life of the individual. A recently reported hormone, sympathin, produced by the smooth muscle cells of the blood vessels and intestines, which acts upon the sympathetic nervous system, is also probably dependent upon the same dietary factors as adrenalin.

Iodine, the Key Substance of the Thyroid Gland

The thyroid has sometimes been called the gland of glands because its activity makes life worth while. It is a controller of vitality and growth and indefatigable protector against intoxicants and injuries. It acts as energizer and lubricator

for the adult, as well as growth catalyzer and developer of the tissues of the bodymind for the child.

The gland, located in the neck, sits astride the upper windpipe, around the larynx. It may become quite prominent, when its enlargement constitutes the condition called 'goitre'. Its secretion is known as 'thyroxin'. The striking fact in the chemistry of thyroxin is the presence of iodine. The other important constituent of thyroxin is a derivative of the amino-acid, tyrosin. Disturbance in thyroxin production occurs either because of difficulty in getting iodine or an insufficient supply of tyrosin.

Iodine is beyond question the food element upon which the functional integrity of the thyroid gland is dependent. The thyroid gland needs a constant supply of iodine or iodine-containing food in order to maintain the requisite amount of thyroxin in the tissues. For hundreds of years the Chinese used sponge in the treatment of cretinism, which is the classic thyroid deficiency of children. Sponge contains iodine.

As long ago as 1850, Chatlin, a French physician, suggested that goitre, a name then given to unexplained swellings of the thyroid gland in the neck, was due to a low iodine content of the drinking-water, air, or food in any country. He tested his theory by feeding iodine in various forms to his patients and obtaining results. His professional rival, Saint-Lager, aided by the prestige of official position, opposed his views and discredited the use of iodine in the treatment of goitre for a whole generation. Subsequent generations of medical men have never learned from him that authoritarians are always wrong.

Since then a host of observations have accumulated to prove that the Chatlin idea was correct. With the discovery of the curative power of thyroid extract in cretinism, enthusiasm concentrated upon attempts to separate the active principle in the thyroid extract from the other relatively useless substances. It was in the course of a research thus inspired that Baumann in 1895 found iodine in the thyroid and demonstrated that the iodine was an essential constituent of its active principles.

Since then it has been shown that the size of the thyroid in various peoples, in all parts of the world, varies with the supply of iodine. That iodine varies in different locales has been

determined by analyses of drinking-water, or of the soil through which the water filters, or of the vegetables and fruits which form the diet of the population. Even the milk of the lactating animals which drink the water and eat the vegetation of a region may be low in iodine and so may be responsible for goitres.

Endemic goitre occurs in mountainous or rocky soil where there has been no deposit of sea material. For all the iodine in the world must be traced back to the sea. And all living creatures which have, like Venus, originally come out of the sea, are still dependent upon the chemical ghosts of the sea, inhabiting the molecules of iodine-containing foods, for the continued normal existence of their bodymind, in its most literal sense of *intelligence*. No sea-inhabiting organisms ever have goitre.

Since 1907, Marine has made a number of fundamental contributions to the relation of iodine in food and iodine feeding to goitre. He found that if there is a relative iodine starvation—an inadequate iodine intake by way of food or water—there is first a decrease in the stored iodine of the thyroid cells. No other changes, gross or microscopic, take place until the reserve iodine has been lowered to a definite point. Then, as the body calls for its regular ration of the thyroxin, the reserve thyroxin is mobilized. This is in the shape of the substance known as ' thyreoglobulin ', deposited as colloid, a compound of thyroxin with protein. In the next stage the thyroid cells begin to work overtime. They hypertrophy and multiply, and the coarse enlargement of the thyroid well known as goitre becomes evident. It is all characteristic of what happens in any gland when it is strained to produce enough of its hormone. There is first loss of reserve power, then strain, then fatigue, and then disease.

This condition of thyroid strain may be handed on from mother to child. Pups born of a dog fed on a low iodine diet and with three-fourths of the thyroid removed, had enlarged goitrous thyroids themselves. They also had a low iodine content. During another pregnancy, the same mother was fed iodine, and the pups of that litter had normal thyroids. How important proper feeding of the mother is for the birth of young with healthy, ductless glands is proved by that experiment, as well as by other experiments involving the other endocrine glands of the mother. Treatment of the

mother prevents the appearance of endocrine glandular disease in the offspring.

In the Yellowstone River Valley, there was an annual loss of millions of dollars' worth of lambs, calves, colts, and pigs due to iodine deficiency and thyroid disease. Pigs were born dead and hairless with enlarged necks. By the administration of small doses of iodized salt to the pregnant beasts, the entire situation was controlled.

In certain prenatal human clinics, the thyroid of mothers is now carefully watched and iodine or thyroid is administered if there is any sign of thyroid trouble. Every woman who intends bearing a child should have her thyroid examined and a basal metabolism test done every month during her pregnancy to prevent transmission of an inadequate thyroid to her helpless children.

The amount of iodine necessary to prevent goitre is exceedingly small. It should not fall below one milligram per gramme of gland. But the amount necessary varies with the other constituents of the food and the rate of function of the other endocrine glands. Cabbage and liver, for instance, make imperative the increase of iodine in a diet, while butter and cod-liver oil decrease the need for it.

Goitre used to be a common practical problem in fish hatcheries. Salmon and trout fed liver always developed goitres. The addition of what amounts to traces of iodine to the water cured the fish, making them lose their previously obvious goitres. When sea food was added to the diet of these domesticated fresh-water goitrous fish, there was also great improvement, to be explained by the presence of iodine in the sea fish. Sea food is one of the most valuable aids in the treatment of thyroid abnormalities.

Other food deficiencies also play an important role in the proper functioning of the thyroid. It atrophies in general deficiency of the vitamins and it enlarges when an excess of proteins or fats is consumed. In human malnutritional oedema, associated with lack of protein, it atrophies.

For a long time after Kendall isolated crystalline thyroxin, it was believed that the thyroid hormone was an iodized derivative of the essential amino-acid, tryptophane. It was considered that tryptophane was necessary raw material for the gland. But a number of researches failed to substantiate the idea. The Australian Hicks in 1926 showed quite conclusively

that there is no proportionality between the tryptophane content of a diet and the thyroxin production. Finally the chemical formula of thyroxin was worked out by Harrington and Barger and also synthesized by them. Upon the basis of their work, thyroxin is now artificially manufactured and we are no longer dependent upon animals for it. The amino-acid tyrosin is just as necessary for the thyroid as is iodine. High tyrosin foods are of value in the treatment of thyroid conditions by diet. Tyrosin is also valuable for the making of adrenalin and other hormones.

Control of goitre is being achieved the world over by iodine therapy. For centuries so-called endemic goitre areas, regions where goitrous enlargement of the thyroid affects a large percentage of the population, have been known. As knowledge of the preventive action of small doses of iodine spreads and is applied, these promise to disappear slowly but surely. In some places iodine in the form of an iodized salt is added to the water or used as regular food seasoning. In others a bottle of iodine is left open in the home or schoolroom, enabling the sufferers to breathe the sublimated iodine as it evaporates.

By far best known of these endemic goitre lands in the United States are the Pacific North-west, the States bordering the Great Lakes and the St. Lawrence River, and the States of Colorado and Utah. In Europe they comprise the Alpine mountain region, which means all of Switzerland and the parts of France, Italy, and Germany adjacent, as well as the Balkan States. The condition which has made the Balkans the firebrands of Europe may be cured when their iodine supply is improved. In Asia, goitre is prevalent in Himalayan Mongolia. There can be no doubt that the percentage of morons and inadequates is high in these parts of the world because of the iodine-thyroid deficiency.

The goitrous tendencies of a district may be recognized from its prevalence not only among its human beings, but also among its lower animals. The experience of Keith, reported in 1924, is typical of the iodine-thyroid relationship as it affects all the living creatures of a neighbourhood. He made a thorough study of the Pemberton Valley in Canada. Every child born in the valley, most of the women, and many of the men, had a goitre. Mares developed goitre and carried beyond full terms their colts, who showed at birth evidence

of thyroid insufficiency. Calves were born goitrous and pigs hairless. Many fertile eggs of fowls developed up to a certain point, but failed to hatch because of a marked thickening of the white envelope within the shell. No cases of goitre were located among the native Indians of the district or their domestic animals because they fed upon large quantities of salmon, an iodine-containing fish. When iodine was administered by Keith to the white inhabitants and their animals, goitres almost disappeared.

McClendon has made some interesting studies of the iodine content of water and foods, which have thrown light on the problem, re-inforcing all previous views. He has shown, for instance, that the water of Lake Superior has about one part of iodine in one hundred billion parts of water, while the water of the lower Mississippi Valley contains ten thousand to fifteen thousand parts of iodine to the same proportion of water. Cereals and vegetables grown in goitre-free districts have one hundred to one thousand times more iodine than in the Lake Superior country. He has calculated that it would require ten years for an adult to acquire from the food and water in a goitrous district the amount of iodine necessary to maintain normality of the thyroid.

However, though all of these prove the key position of iodine in thyroid functioning and the importance of the iodine content of food and water in determining the efficiency of the thyroid, it should not be hastily assumed that all goitres or all thyroid conditions can be exorcized by iodine or iodine-containing foods. Even though Plummer has shown the efficacy of iodine in exophthalmic goitre as well as in endemic goitre, every thyroid should be treated upon its own merits and for its own indications. Iodine may do harm where thyroid substance itself or thyroxin do good and vice versa. But there can be no doubt that the iodine content of food and water should be considered in every thyroid problem presenting a psychological side—for example, certain cases of dementia praecox.

The Parathyroids: Stimulated by Calcium

The parathyroid glands are most directly affected by Vitamin D and calcium salts. These parathyroid glands are four little organs which are placed in such close proximity to the thyroid that they were confused with it and considered part

of it until fifty years ago. Parathyroids are not present in fish, because there is plenty of lime in the sea, which makes it unnecessary for them to have any regulator for it. Also, fish have the capacity to manufacture Vitamin D in their livers and need no regulator of Vitamin D. But all land animals, amphibians, reptiles, birds, and mammals, including man, are absolutely dependent upon an outside source of lime and Vitamin D. They develop signs of deficiency or starvation of them quite easily.

So the parathyroid glands have been evolved and are present in all land animals to conserve and regulate their supply of calcium and Vitamin D. If there is a lack of lime or Vitamin D in the diet, the parathyroids function to economize the calcium and Vitamin D already present in the bodymind. Consequently, the parathyroid glands enlarge in calcium deficiency, or Vitamin D deficiency, as a result of overwork, just as the thyroid glands enlarge in iodine deficiency serving overtime to make extra thyroxin.

Parathyrin, the internal secretion of the parathyroid glands, was isolated by Berman in 1923. It regulates the amount of lime in the body, mobilizing it out of the bones into the blood for distribution to the soft tissues, especially the nerves. A constant balance has to be maintained between the lime in the blood, in the soft tissues, and in the bones. When there is a deficiency of lime in the food, the stores of it in the bones must make good the lack, by surrendering to the blood some of the calcium. The body's means of forcing such a discharge of lime from the bones is parathyrin.

In experimental rickets, which can be produced by reducing or eliminating the phosphorus content of a diet, or by feeding food in which there is a striking lack of balance between the phosphorus and calcium, or by means of a diet deficient in Vitamin D, there occurs an enlargement of the parathyroid gland, due to an increase and multiplication of its cells. There is thus evoked a regular response of compensation for the dietetic deficiencies in calcium or phosphorus. The reaction may be prevented by the administration of viosterol or Vitamin D.

Vitamin D assists the bones to take up calcium and phosphorus from the blood and relieves rickets. Vitamin D acts in a direction opposite to that of parathyrin, which causes withdrawal of calcium from the bones into the blood. That

is, Vitamin D facilitates retention of calcium by the bones, because it facilitates the assimilation of calcium and thus tends to relieve the parathyroids of strain.

Besides, there is good evidence that Vitamin D has a stabilizing action upon the parathyroid glands themselves, and acts through them. For without the parathyroid glands, Vitamin D exerts its specific effect only with difficulty and only slightly. A sufficient intake of Vitamin D is necessary to maintain the parathyroid glands in the best of conditions.

Parathyroid deficiency is accompanied by a great sensitivity of the nervous system. The parathyroid-centred individual presents temperamental characteristics quite peculiar to him which often tend to make him an a-social or even an anti-social member of society. The parathyroids and calcium metabolism have a definite relation to the neurotic constitution.

High calcium foods are milk, cheese, carrots, cabbage, turnips, oranges, prunes, beets, and apples. Low calcium foods are the refined sugars and cereals, meats and fats. Vitamin D-containing foods are egg yolk, cod-liver oil, liver, the fatty fish, and foods artificially treated with ultra-violet light.

Nourishment for the Sex Glands

The gonads are the generative and reproductive glands. In the male they are the testes; in the female, the ovaries. Since they have definite canals for the removal of their secretion, they are first of all glands of external secretion. But they also have interstitial cells which manufacture an internal secretion.

These interstitial glands make the primary stimulants of the genital sense and flair of the individual. All that moves the individual to the depths of his being in sexual excitements and reactions is absolutely dependent upon the amount of internal secretion manufactured and delivered into the blood by these interstitial cells. And so important are they, too, for the bodily well-being of the individual that their degeneration synchronizes with the gradual breakdown of the tissues which leads to senility.

A liberal amount of protein is necessary for the normal evolution of puberty. Slonaker and Card have shown that when albino rats were put on a vegetarian diet, low in protein,

there resulted delayed puberty and sterility, so that families became extinct by the third generation. When placed on a diet containing plenty of protein, fertility was restored provided the process had not been permitted to go too far. Reynolds and Macomber confirmed these findings and also discovered that calcium deficiency, as well as insufficient calories in general, would cause similar effects.

Evans and Bishop found that a Vitamin A-deficient diet produced a complete interference with the ovarian hormone which regulates the rhythms of the vaginal sexual cycle. These parallel the state of rut (sexual susceptibility and insusceptibility) of the animals. The rhythms were all upset in consequence of a deficiency of Vitamin A. There was a continuous instead of a cyclic production and peeling of the peculiar cornified cells of the vaginal mucous membranes. The cornifying changes characteristically accompany the impulse to copulate. Heat and copulation occur. Yet there is an impairment of the ova, so that fewer of them are generated in a state of maturity. A reduction of fertility occurs.

It has been shown that just as ergosterol is the raw material precursor of Vitamin D (viosterol), so carotene is the raw material of Vitamin A. And just as there is a large amount of ergosterol in mushrooms, there is a large amount of carotene in carrots. Viosterol is made from ergosterol in the skin and in the blood flowing through the skin, while Vitamin A is made from carotene and the liver.

Recent experimenters reported that Vitamin A (also Vitamin B) give off radiations which are similar to the rays of the X-ray and radium. These are known to produce most powerful effects on living matter. Vitamins, then, may serve to energize the bodymind directly by means of these vibrations, as well as by serving as raw material for the factories of the glands of internal secretion. These experiments may explain why Vitamin A and Vitamin B are so important for the sex glands.

Vitamin B deficiency causes simply a general degenerative atrophy of the ovaries, as has been observed in beri-beri. Vitamin C is also necessary for ovarian nutrition, for in scurvy there is a progressive atrophy of the female gonads. A deficiency of Vitamin C in adults may produce a peculiar kind of scurvy anaemia which is injurious to the gonads.

Vitamins A, B, C, a high proportion of protein and calcium,

are thus seen to be required as building-stones for the formation of healthy ova, as well as a requisite number of calories. This is to be expected, as the sex glands are so sensitive to any defect or discouragement of their environment. Of these the most important for the integrity of the ovaries is Vitamin A.

Vitamin E and Sex

But the food substance which has been shown to be peculiarly related to the sex glands and the reproductive apparatus, especially the uterus, is Vitamin E. The non-pregnant uterus is fairly resistant to most of the types of malnutrition to which the ovaries are sensitive. But the pregnant uterus is quite different.

The pregnant uterus is characterized by the presence of a new organ, the placenta. The placenta is formed as the outcome of an interaction between the interior of the uterus and the developing fertilized ovum which has settled in it to live for a time its parasitic existence. It is expelled after parturition as the ' after-birth ', and has been demonstrated to contain large quantities of ovarian, pituitary, and other hormones, some stored there from the blood of the mother and some manufactured by itself.

The placenta acts as a filter, preventing harmful or disturbing substances from reaching the evolving foetus. If, for instance, the large quantity of ovarian hormone circulating in the blood of the mother could enter the blood of the developing male, it might give the creature a twist in the direction of femininity, which would interfere with its normal sexual evolution, producing an intermediate. This is what happens in the case of the ' free-martins ' of cattle, twins of opposite sex. They have a common circulation, and the male hormones, formed earlier than the female, act upon the female to make it a sterile intermediate creature. Such an interference, due to the action of the hormones of one sex upon that of the other, is prevented by the placenta retaining the mother's hormones of sex, at any rate. Similarly, the prepituitary growth hormone could, in the large quantity proved present in the mother's blood, stimulate the occurrence of giantism in the about-to-be-born infant, which would make Caesarean sections necessary for every birth. The placenta prevents this misfortune also by its filtering action.

Acting as lungs, ice-box, and policeman for the embryo, the

placenta is therefore a most important organ. Now, Evans and Bishop have found that a normal placenta cannot be formed or persist without a regular supply of the food substance first named Vitamin X by them and finally called Vitamin E. In the absence of Vitamin E, in an otherwise completely balanced diet, the ovaries seem to function properly, and the sexual cycles recur as they should and the ova become fertilized and implanted in the interior of the womb to go some way along the line of the embryonic patterns. But sooner or later abortion happens.

The abortion is due to abnormality of the placenta. Even as early as the second day of its establishment, the placenta begins to show haemorrhages, which increase in amount and extent. In the diseased placenta, the embryo cannot go on. It dies and is absorbed and the placenta is abortively expelled. Or a commonplace abortion is produced, when both arrested embryo and sickened placenta remove themselves from the scene.

Animals not fed a sufficiency of Vitamin E are clinically sterile. If the mother is supplied with fresh lettuce, the seeds and green leaves of other plants, egg yolk, fresh meat, animal fat, or unmilled cereals, such as wheat-germ oil, all foods which have a large content of Vitamin E, the destructive process ceases and normal young are born.

Nägeli and other haematologists have also presented evidence that the ovary assists in the assimilation of iron. That observation is interesting because clinicians have long associated chlorosis, the 'green-sickness' of young girls, with an abnormality of the ovaries that is curable with iron. An adequate supply of iron is probably specifically related to integrity of the ovaries. The high iron foods, grouped in their order of concentration, are Lima beans, peas, whole wheat, lean meat, spinach, oatmeal, raisins, eggs, and green vegetables.

Copper has recently been shown to be valuable for the adequate utilization of iron, which makes it a factor in the genesis of certain of the anaemias. The following ten foods possess the most copper: wheat germs, oats, almonds, kidney beans, rye, peas, asparagus, corn, lentils, and barley. Vitamin E, grossly prerequisite for the placenta, is also needed, but more subtly, for the normal ovary.

In the case of the male, sterility is also the effect of a lack of Vitamin E. But while in the female the Vitamin E defici-

ency apparently affects the generation of the ova not at all, in the male, the production of sperm is markedly disturbed, leading to permanent and incurable sterility. Young males of mothers fed plenty of Vitamin E become sterile after the fourth month if weaned on the twenty-first day and dieted on Vitamin E-deficient food. Sterility develops in four stages of severity. First, there occur approximately natural sex responses with abundant sperm, but loss of fertilizing power. Second, there is complete absence of sperm with, of course, sterility. Third, there is loss of ability to form a vaginal plug, characteristic of successful intercourse. Fourth, there is loss of all sex interest. Restoration of the testes may be effected if Vitamin E is fed in the first or second or third stages, but the testicular degeneration and sterility are permanent if the fourth stage has appeared. No cure is then possible by feeding Vitamin E.

Unlike the effects of Vitamin A deficiency upon the ovaries, a lack of it in the male causes a disturbance of sexual behaviour. A complete loss of libido with sterility follows early disinclination to copulate. Deficiency of Vitamin B causes no injury to the male germinal elements comparable to the action of Vitamin E inadequacy.

In chickens, in whom atrophy of the testes has been produced by a vitamin-deficient diet, there is an inhibition of the growth and development of the secondary sex characteristics (spurs, comb, and tail feathers). This fact shows that Vitamin B also has a definite relation to the manufacture of the internal secretion of the testes. This is probably mediated through the prepituitary.

Of the other foods, protein is as important for the preservation of the testes as of the ovaries. Slonaker and Card found with the testes, as they did with the ovaries, that a protein-poor vegetarian diet delayed puberty and increased the occurrence of sterility. In malnutritional oedema, such as the human war oedema, with lack of protein and fat, Reach observed atrophy of the testes, incompletely descended in many cases. It was accompanied by associated disturbances of their endocrine functions.

Vitamins for the Pituitary Gland

The pituitary is a gland of many functions and many hormones. Conventionally spoken of as a single gland, it is

undoubtedly two glands in one, each producing several hormones. These two glands are described as the prepituitary or anterior pituitary and the post-pituitary or posterior pituitary.

The *prepituitary* or anterior pituitary gland controls growth during childhood and adolescence, sexual development and maturity, and sexual metabolism. The prepituitary is necessary for the proper evolution of the sex glands, such as occurs at puberty. An artificial precocious puberty may be achieved in animals experimentally by injecting prepituitary extracts. In the individual's lifetime, the age of maturity may be described as the epoch of the prepituitary.

The *post-pituitary* regulates the water-balance of the body, blood pressure, tone of the gastro-intestinal tract and of the sexual tract, and has an influence on sugar and fat metabolism. It is also correlated with the pigmentation and complexion of the skin. It may be inferred that it is an organ of no little significance for the well-being of the organism. Much work remains to be done on the relation of the different food essentials to the post-pituitary. But it is probable that whatever affects the prepituitary also affects the post-pituitary.

The peculiar relation of the post-pituitary to water metabolism would make it plausible that it would react to a deficiency of water with hypertrophy : in the same way the thyroid gland reacts to a deficiency of iodine and the parathyroid glands to a deficiency of calcium. And, indeed, the Japanese, T. Kudo, in his interesting studies of the effects of thirst or water deficiency upon the weights of different organs and systems in albino rats, found but little change in the average weight of the gland in the shorter test periods, but a definite enlargement in the longer test periods. But he makes no mention of a separate weighing of the prepituitary and post-pituitary portions of the gland. From that, one may only surmise that the increase in weight of the pituitary gland with lack of water may be due to augmentation of the cells of the post-pituitary. But there can be no doubt that an insufficient water supply would involve post-pituitary strain, and that an adequate water intake is valuable for maintenance of a normal post-pituitary. On the other hand, an excess of water for a deficient post-pituitary individual would be a mistake.

As regards the prepituitary, McCarrison has pointed out the interesting fact that a diet which will cause atrophy and degeneration of the testes will cause hypertrophy and enlargement of the pituitary. He has also emphasized the similarity of this reaction of the pituitary to its reaction in castrated animals, and to the appearance of the pituitary in eunuchs. There is a likeness, as well, to the well-known enlargement of the pituitary, with accompanying clinical phenomena of acromegaly, which occur regularly in pregnancy.

The effect of a defective diet which damages the testes—that of deficiency in Vitamin B, for example—does, in fact, castrate it, physiologically and psychologically. It would appear, then, that Vitamin B is as important for the prepituitary as E is for the testes and the placenta. And, indeed, Evans and Simpson have shown that the pituitary glands of the B-deficient are definitely lacking in the sex-affecting hormones. More Vitamin E is found in the prepituitary than in any other gland.

McCarrison has also emphasized that the tendency of the pituitary to enlarge in consequence of food deficiency is much greater in males than in females; because deficiency in Vitamin B causes degeneration of the testes, but not of the ovaries. This is what one would expect if the reaction of the pituitary to Vitamin B deprivation is a castration reaction, comparable to its reaction in eunuchs. Vitamin B, then, seems to be the vitamin characteristically necessary for the pituitary gland.

Besides Vitamin B, manganese has a relation to the prepituitary. It is similar to that of copper to the blood and calcium to the parathyroids. Normal functioning of the prepituitary involves the metabolism of manganese. McCollum has shown that animals deprived of manganese lose the maternal instinct, refuse to suckle their young (they do not have proper development of the mammary glands, nor do they secrete normal milk for their young), nor do they make a nest for them, and will even eat them. To prevent pituitary strain, attention must be paid to the manganese content of a diet in selected individuals.

The high manganese foods are potatoes, lettuce, agar-agar, wheat germs, liver, and peanuts, walnuts, and almonds. These are the most common sources of it, but many other fruits and vegetables contain an abundance of it.

10

Cystine—A Prerequisite for the Pancreas (Insulin)

The pancreas is of interest as an organ of internal secretion because it holds the islands of Langerhans, the cells of the insular gland, which makes insulin, the preventer of diabetes.

Besides insulin, the pancreas manufactures another hormone, kallikrein, which has been used for several years in Germany as a means of dilating the blood vessels. By its injection into the muscles, high blood pressure, not due to kidney disease, may be reduced and attacks of apoplexy and paralysis prevented. It has proved extremely useful in angina pectoris, which is caused by a spasm of the coronary arteries of the heart. In certain diseases of the limbs which terminate in gangrene and necessitate amputation, kallikrein proved capable of opening the blood vessels and obviating operation. No special relation of food to kallikrein has been as yet demonstrated.

Through insulin, the pancreas is the gland which is the controller of sugar metabolism. There is no doubt now that insulin reacts to the sugar of food. The more sugar is taken in a diet, the greater is the demand upon the insular gland of the pancreas for insulin. But also, the more fat there is in a diet, the greater the demand for insulin, for sugar must be burned to burn the fat, and insulin facilitates the burning of both. The transition from a state of continuous overactivity to a state of strain is easy, when the diet is overcharged with sugars and fats. And that is why in those predisposed (those with a congenital latent weakness of the pancreas) diabetes develops as a result of strain produced by the overeating of sugar and fat (before the limit of tolerance is broken). Indiscretions may be spread over a series of months or years.

Quite a tremendous increase in the consumption of sugar per individual has occurred in all the great countries of the world in the last hundred years. About three hundred years ago refined sugar was regarded as a luxury of the extremely rich and used only as a condiment. Its more general use has paralleled the rise of industrialism and the concentration of populations in cities. In 1821, according to the United States Department of Agriculture, the yearly consumption of sugar in America was 7 pounds *per capita*. In 1925, it had risen to 121 *per capita* per year, an increase of 1,600 per cent. A similar though not so spectacular a phenomenon has been recorded

for France, Germany, and the United Kingdom. In the last, for instance, the annual *per capita* consumption of sugar was 16 pounds in 1821 and 95 pounds in 1925, an increase of about 500 per cent. The use of refined sugar has become widespread, partly as a result of cheapening of production and partly as the outcome of advertising, stimulating a taste for confectionery, pastries, and sweetened drinks.

Now, refined sugar causes more of a strain on the insular glands of the pancreas than any other form of carbohydrate because it is so quickly digested and absorbed. In fact, it may be said to enter the blood stream, to reach the liver, almost immediately after ingestion. Under certain circumstances, and when repeated day after day for years, the insulin mechanism is bound to be injured and the carbohydrate tolerance ruined. Four diseases have increased strikingly in the last hundred years, parallel with the increase in the consumption of sugar—diabetes, obesity, stomach ulcer, and cancer.

The relation to diabetes and obesity is easily understood. In cancer it has been recently found that the blood sugar tends to be high and the carbohydrate tolerance is much limited. Cancer is also more prevalent among the obese, as is gall-bladder disease. Deeks was one of the first to point out the intolerance of stomach ulcer patients for sugar. And many dermatologists believe that eczema is a symptom of intolerance for sugar. All in all, there can be no question that to maintain an adequately functioning, and yet normally regenerating, insular gland, in the pancreas, the limits of sugar tolerance should not be greatly overstepped.

Two other elements in food have been implicated in insulin metabolism. They are sulphur and nickel. Sulphur is a constituent of the insulin molecule. An attempt has been made to show that sulphur is to insulin what iodine is to thyroxin. Sulphur is present in the amino-acid cystine. Sulphur is undoubtedly concerned importantly in the oxidations within cells. As insulin facilitates the combustion of sugar within cells, the idea is plausible. So high sulphur-containing foods might be of value in certain types of insulin deficiency. As regards nickel, Bertrand, the French biochemist, has found a relatively considerable quantity of it in the pancreas. He has even advocated the use of it in the treatment of diabetes. For insulin, which is really a special

kind of amino-acid derivative, glutamic acid and cystine must be supplied in the diet, as Jensen has shown that they are the characteristic components of its chemistry.

Summary of Endocrine-Food Relations

All the facts and possibilities considered in this chapter show how knowledge of the relation of food elements to the different glands of internal secretion can be used in making diets to suit the individual and his individual needs. If study and examination of an individual demonstrate a glandular weakness or imbalance, such diet can be employed to aid in the correction of the condition, with favourable results for personality and efficiency all along the line. Many people, who pass for normal, do present some evidence of some basic endocrine defect in their make-up. Their diet might be modified favourably as a measure of preventive medicine. This may turn out to be *the* mode of attack upon the problem of preventing the degenerations of middle age.

Endocrine Glands	*Food Requirements*	*Personality Characteristics*
Thyroid	Iodine Anti-goitre foods Tyrosine	Excitability (mental agility and speed)
Parathyroids	Calcium Vitamin D	Sensitivity (irritability)
Adrenals	Vitamins A, B, C, G (C = hexuronic acid) Tyrosine Cholesterol Magnesium	Driving power (resistance to fatigue)
Thymus	Vitamin B	Immaturity (perversions)
Pituitaries		
a. Prepituitary	Manganese Vitamin B Histidine	Maturity (intellectuality)
b. Post-pituitary	Water Salt (chloride) Histidine	Emotionality (emotional control)

Endocrine Glands	*Food Requirements*	*Personality Characteristics*
Pancreas	Sulphur Cystine Glutamic acid Glucose Nickel (?)	Endurance
Sex Glands (Gonads) *a.* Ovaries *b.* Testes *c.* Placenta	Vitamins A, B, C Vitamin E Tryptophane Lysine Iron Linolenic acid	Sexuality

This table is by no means complete. It summarizes what is known to-day of the feeding requirements of the endocrine glands in relation to character and personality.

This matter of the specific feeding needs of the endocrine glands illustrates the principle that the feeding of the body-mind means the feeding of its organs. It is a mistake to believe that all organs require the same kinds and amounts of foods. Each organ is constantly undergoing a process of growth and repair, which keeps it in a state of balanced harmony with every other organ. Food supplies the building-stones of growth. But not all organs use the same materials. When any organ—particularly the endocrine glands—is not functioning as it should, the following principles can be applied to assist in strengthening its activity and regulating the output of its work.

1. Not all organs are equivalent as regards their needs of the different food substances.
2. Each organ has its own special dietetic and metabolic requirements which must be fulfilled for it to function at its best.
3. The reactions of an organ to specific food deficiencies or excesses can be used as a means of determining its needs.
4. When an organ is strained, exhausted or diseased, a diet can be given which will hasten materially its recovery and contribute to the return of its reserve power.

A tremendous amount of work remains to be done in this important field. It is connected with the whole problem of cancer (an abnormal organ growth). But enough is known

to employ most satisfactorily in the treatment of various organs, the endocrine glands in particular. The use of liver and liver extract in pernicious anaemia is a perfectly good example of how supplying extra nourishment to an exhausted organ (the bone marrow) results in a rejuvenation of its power and function to produce red blood cells. The future of disease and health may be said to be dependent upon the extension of our understanding of how to feed organs *specifically*. It is of the greatest interest and importance that the indispensable amino-acids, cystine, histidine, tyrosine, tryptophane, and lysine are the mother substances of the thyroid and adrenal, the pituitary, pancreas and sex-gland hormones which have been shown to be so necessary for health and efficiency. The other substances listed are essential either as catalysts or adjuncts for their manufacture.

CHAPTER V

CHEMICAL DIFFERENCES IN HUMAN BEINGS

WHAT are people made of ? The traditional question-begging answer has been : flesh and blood. And the nursery rhyme distinguishes the female's sugar and spice from the male's sticks and stones. And the answer to the second question of the Catechism, ' Of what are you made ? ' is, ' The dust of the Earth.'

The chemist has shown that human beings are mostly water. They are also compounds of carbon and nitrogen, hydrogen and oxygen, with a large number of other elements. Among these elements are iodine and lime and iron, and sulphur, magnesium, and phosphorus. Human beings represent different combinations of these elements. Excepting, perhaps, identical twins, no two human beings ever have exactly the same chemical composition.

Of the ninety-odd elements which compose the universe, some thirty-three, or about a third, have been identified in various living protoplasms, as follows :

Aluminium	Helium	Oxygen
Argon	Hydrogen	Phosphorus
Beryllium	Iodine	Potassium
Boron	Iron	Rubidium
Calcium	Lithium	Scandium
Carbon	Magnesium	Silicon
Chlorine	Manganese	Sodium
Chromium	Neon	Sulphur
Cobalt	Nickel	Titanium
Copper	Nitrogen	Vanadium
Fluorine		Zinc

As man has come out of the earth and the sea, it might be expected that all the elements of the earth and the sea would be found to be part of his being. Probably it will ultimately

turn out that every known element plays some definite function in his life. Only, whereas most of those listed occur as indispensable chemical traces, the others will be discovered as spectroscopic traces, traces of traces, but invaluable nevertheless.

An interesting summary, in terms of common values, has been made of the chemical composition of the 'average human'. The iron in his bodymind is just about enough to make a medium nail. The lime might suffice to whitewash a chicken coop. There is enough phosphorus to make 2,200 match-tips. The potassium would just about do to explode a cannon. There is enough magnesium to make a dose of magnesia and enough sulphur to make a dose sufficient to cure a dog of fleas. All the fat in the average person would make about seven bars of soap. All the sugar would just about fill a shaker. The total cost of these ingredients is given as about four shillings. These figures were worked out by the Marathon Paper Mills Company some ten years ago.

The figures for the blood are even more startling. The total volume of the blood in an adult human being corresponds to that of about half an ordinary pail or bucket. The sugar in that half-bucket amounts to about a teaspoonful. That teaspoonful of sugar is mighty powerful. If it dwindles to about half a teaspoonful, the individual becomes so weak that he faints and has convulsions. If it should become two teaspoonfuls, he has diabetes. The amount of salt in that half-bucket of the fluid of life is about a tablespoonful. The amount of fat varies from about one teaspoonful to about one tablespoonful. The amount of cholesterol, the peculiar waxy solid alcohol, which is like a fat and yet not a fat, indispensable for so many of the reactions of life, corresponds to what can be extracted from twenty-four egg yolks. The amount of iodine in the blood, which is so intimately related with the function of the thyroid gland, is about one one-hundredth of a grain.

Altogether about a thousand different chemical substances have been found in the human organism. Most of them occur in amounts that are slight but curiously effective. Human beings are mixtures of these thousand compounds, in varying proportions. The chemical difference between two human beings may be slight, but the effects on the personality are

tremendous. A person in a state of acidosis is quite unlike one in a state of alkalosis. Yet the 'acidity' of acidosis is about equal to the acidity of distilled water, while the 'alkalinity' of alkalosis is that of tap-water. It takes delicate chemical tests to distinguish ordinary water as it runs out of a faucet from the distilled water of bottles. This provides some conception of the extremely narrow range within which the balance of personality may swing.

Bound up with the understanding and control of these thousand and one chemical constituents of personality is the understanding and control of the entire future of the human race.

Seven years ago, Thorpe, a British chemist, wrote:

> In the not far distant future the whole subject of biochemistry, which is the chemistry of life, will form but a part of organic chemistry, and we shall be able to apply to it the means and methods which have been attended with such astounding success during the past sixty years in the treatment of the parent science. When this is the case, the causes of our bodily ills will be as clear as the structure of indigo; and their removal as easy as a test-tube reaction. The treatment of disease will be as sure and as certain as the neutralization of ammonia by sulphuric acid.

Many advances have taken place since to confirm the validity of that prophecy.

Chemical Classes of People

'Dust thou art and unto dust shalt thou return.' Thus the primeval God cursed his primeval creatures when they sinned. From dust unto dust, it has been put, and from lust into dust it might have been said. Descendants of the accursed have taken the anathema to heart and concentrated upon an analysis of the burning dust of their being. And they have penetrated as far into knowledge of it as they have into the secrets of the galaxies of burning dust amid which they whirl —the stars of infinite space.

By means of the balance, the combustion furnace, the microscope, the colorimeter, and the other apparatus of a chemical laboratory, the essential chemical characteristics and differences of people may be established. The various fluids which reflect the chemistry of the tissues—the blood, the

urine, the saliva—may be as carefully analysed as is scientifically desirable. The blood, particularly, is a remarkable mirror of what is occurring in the fixed cells of the bodymind, since it is itself a special tissue, but a floating tissue which commingles with all the others. By comparing its composition with that of other fluids, a remarkable insight into the individual is obtainable.

Human beings differ in their chemistry and in their chemical contents for several reasons. We know practically nothing of differences in the chemistry of different germ plasms, or of the chromosomes and genes composing them. But it is known that the food of the mother plays a most important role, since the developing embryo is dependent upon her for its nourishment. Being born prematurely, or after the proper time, may make a great difference. During the last three months of its life within the womb, mineral salts are stored in the liver of the growing child for its use after birth. Particularly is this true of the lime and iron needed for the making of bone and the manufacture of red cells. This storage of iron and lime in the foetus is accompanied by a decrease of lime and iron in the mother. Premature infants and twins thus begin life with a mineral deficiency. They are thus predisposed to the development of anaemia, rickets, and a neurotic temperament.

Feeding conditions after birth also play a dominating role in determining the chemical constitution and resistance of the child. It has been proved that an adult, apparently normal as far as outward appearances go, may be iron-poor, or lime-poor, or vitamin-poor to an extent which will be revealed only under stress and strain. Such exaggerations of type conditions show that all individuals must present a range of chemical composition as regards all substances entering into their make-up, ranging between a high normal and a low normal, with latent pathological possibilities. In other words, during childhood, the bodymind may be either starved or overfed, in relation to one or another of the foods, with tremendous consequences for the endocrine glands and personality of the individual.

Depending, therefore, upon how much the personality was fed before and after birth through puberty to maturity, there are different chemical classes of people which can be correlated with different glandular types.

Serial Reactions versus Circular Reactions

No two human beings have the same metabolism or bodymind chemistry, because no two people are made up of the same number or the same amounts of chemicals. Nor do the same quantity or kinds of chemical reaction occur in any two people.

Yet human beings may be and are sufficiently similar in their chemistry to make it possible to speak of types of metabolism. That is, there are varieties, characteristic classes of bodymind chemistry, which individuals approximate. It is the task of endocrinology to explore this chemical classification of human beings. Intimately a part of this job is the investigation of the influence of food on character.

There being a thousand and one or so different chemical compounds in the body, thousands of chemical reactions are going on every minute, every second, in the cells. Any two or three chemical compounds may react to form other compounds. One chemical reaction follows another in series (serial reactions, one-two-three reactions, a chain of reactions in which the products of one reaction lead to the development of another reaction). Such is the series of reactions by which sugar is converted into water and carbon dioxide. The hormone, theelin, of the ovary, produces reactions in the uterus which are a necessary preliminary to the action of progestin, the hormone of the corpus luteum. Pregnancy cannot take place unless this one-two type of reaction occurs.

Another type of chemical reaction is the circular reaction. In a circular reaction there results the re-formation of the original chemical substance with which the reaction started. An example of a circular reaction is the formation of sugar from glycogen through lactic acid back to sugar and glycogen again, which occurs whenever a healthy muscle functions.

Energy for the work of keeping alive is liberated as a byproduct of both kinds of reaction. Water, oxygen, and enzymes regularly enter into such serial and circular reactions. By hydration, the addition of water, and by dehydration, the withdrawal of water, profound cleavages may be made to occur in the complex chemical molecules of the foods. By oxidation, the addition of oxygen, and by reduction, the

removal of oxygen, multifarious circular reactions occur. Energy of heat, besides other forms of energy, such as electricity, or energy of movement, are set free to do work at the same time.

Chemical Reactions in Human Beings

A chemical engine or machine may be defined as a mechanism operated by these serial or circular chemical reactions. The chemical combustion engine which functions in an automobile or aeroplane is relatively simple, as compared with a living machine like a muscle. Feeding of gasoline, its vaporization and mixture with oxygen, the electrical spark which accelerates the reactions between gasoline and oxygen, the resulting production of new chemical compounds which happen to be gases, and therefore must expand, thus evolving energy of motion which moves the wheels of the car, all constitute a serial process easily understood by the owner of any car. The whole is an integrated collection of physical and chemical reactions, which constitutes the fairly well-known formula of self-regulating motors.

Human chemical machines, known as muscles and glands and nerves, are characterized by the circumstance that their reactions are not only serial, but also circular, so that *the machine is not only self-regulating, but also self-repairing or self-regenerating.*

It is important to bear this principle in mind in considering differences between individuals. Metabolism, the chemical fires of life, in any individual consists first of the reactions of the substances of food (the elementary or digested constituents of foods). Then come the reactions of the intermediate substances formed during metabolism (the products of the serial and circular chemical reactions in cells). Finally there are the reactions of the terminal, ultimately evolved substances (the resultants of metabolism called metabolites) which are removed or excreted by the kidneys, lungs, intestines, or skin as harmful or no longer effective. Thus sugar (a food) becomes lactic acid (an intermediate product), which in turn becomes carbon dioxide and water, excreted as end products by the lungs.

Food, therefore, has a picaresque history in the bodymind. There are adventures of digestions, combinations, combustions, and excretions which are most fascinating. Concerning each

of the thousand and one of them, an Arabian Night's Tale could be told.

Catalysts of Metabolism

Now to-day it is a well-established principle that the glands of internal secretion, the endocrine or ductless glands, regulate all these incidents of metabolism. By means of their hormones, they control the fate of food in the body. They effect their profound influence upon food by regulating the production of the intermediate and terminal products of metabolism. An intimate relation of these same glands of internal secretions and their hormones to character and personality has also been definitely established. Foods, hormones, and personality types are correlated.

The glands of internal secretion are the links between food and character. For the glands of internal secretion govern the chain of reactions by which food is transformed into energy, different tissues and personality characteristics. Variations in these same glands of internal secretion are responsible for the significant differences of metabolism and character which distinguish different types of individuals.

In general, chemical reactions, both inside and outside any living organism, are regulated in two ways: First, they depend upon the nature and quantity of the substances involved. And secondly, the speed of their reactions may be made to vary. Two substances may react together for a long time, but so slowly that no apparent change has taken place in them. Such a chemical reaction, which in itself proceeds with the utmost slowness, so that apparently no chemical reaction is taking place at all, may under certain circumstances be speeded into a violent reaction. Explosion takes place upon the addition of a mere trace of a third substance, known as a catalyst. This outsider, the catalyst, acts as a stimulant of the reaction, facilitating it, but itself emerging at the end of it practically unchanged, although it may have gone through a number of chemical adventures during the course of it. It has been said that a 'catalyst is like a tip to a waiter, in that it accelerates a reaction that otherwise would proceed with infinite slowness'.

Although it was known for a long time before his work, the process of the hastening of ordinarily slow and imperceptible chemical reactions was first carefully studied and named by

Berzelius in 1835. At that time he was working on the problem of what happens when sugar ferments and becomes alcohol. In this, one of the best-known reactions of biochemistry, he anticipated a host of subsequent discoveries. For in all animals and plants there transpires continually a multitude of catalyzed chemical reactions. His original statement is worth quoting:

> We had made acquaintance with the fact that, for example, the change of sugar into carbonic acid and alcohol takes place in fermentation under the influence of an insoluble body, which we call 'ferment', and also with the fact that this ferment could be replaced, although less effectively, by animal fibrin, coagulated plant albumin, cheese, and similar substances, as well as with the experience that the process could not be explained by a chemical action between the sugar and the ferment analogous to double decomposition. Comparing it with known relations in the inorganic world, it was seen to be most like the decomposition of hydrogen peroxide under the influence of platinum, silver, or fibrin; it was, therefore, natural to suppose that the action of the ferment was an analogous one.
>
> I will call it the *catalytic* power of substances, and the decomposition effected thereby, *catalysts*, just as we understand by analysis the separation of the constituents of substances by means of affinity. Catalytic power appears to consist essentially in the fact that substances are able to set into activity affinities which are dormant at this particular temperature, and this, not by their own affinity, but by their presence alone.
>
> We have justifiable reasons to suppose that, in living plants and animals, thousands of catalytic processes take place between the tissues and the liquids in the formation of a great number of dissimilar compounds, for whose formation out of the common raw materials, plant juice or blood, no probable cause could be assigned. The cause will perhaps in the future be discovered in the catalytic power of the organic tissues of which the organs of the living body consist.

In fact, it is impossible to conceive of any living organism maintaining its existence for one moment without the help of catalysts. For most of the chemical changes that constitute digestion, metabolism, and excretion would take place far too slowly without them. Not enough energy would be supplied in a given time to keep the cells a going concern. Nor would the marvellous order of the serial and circular chemical reactions be maintained.

Biocatalysts originate in Foods

Of all the amazing things that happen in living cells, that they manufacture their own catalysts out of the food products of digestion is by far the most amazing. They themselves produce their own necessary regulators, the governors and directors of what goes on in them. It is as if an ordinary citizen were to grow his own policeman, his own congressman, his own President.

Numerous catalytic ferments and enzymes have been separated out of cells. All of them have definite powers in causing to take place, quietly, unostentatiously, and with the least expenditure of energy, chemical reactions between substances. Whereas the same can be imitated in the laboratory only by employing a great deal of energy and the production of violent disorder, like the process of boiling, heating, or explosion.

These catalytic promoters of chemical reactions may be most specific : that is, the particular catalyst will act upon one substance, and that substance only, or only one group of substances. In this, catalysts differ from the action of heat, which accelerates most reactions in general, without any specificity of action whatsoever. It is characteristic also of catalysts that they exert their power in very small amounts. One part of catalyst in a million or ten million may be sufficient to hasten significantly and obviously the course of a reaction.

Positive catalysts are those which speed up a reaction. Negative catalysts act to slow up a reaction. The majority of catalysts working in the body are known to be positive catalysts.

It is also known that the activity of a catalyst may be definitely affected by the presence of foreign substances. Foreign substances which tend to interfere with the action of a catalyst are known as poisons. Arsenic, the well-known poison, has a tendency to paralyse the action of most catalysts, even outside the body. In the manufacture of sulphuric acid by the contact process, for example, a platinum asbestos was used for the oxidation of sulphur dioxide. The platinum asbestos was found to deteriorate quickly because of the presence of arsenic in the sulphur dioxide. The removal of the poison made possible the practical employment of the

method, the usefulness of which was seriously threatened by the arsenical poisoning of the catalyst.

In metabolism, during the serial and circular chemical reactions by which food becomes converted into energy and the constituents of the cells, the all-important catalysts are the hormones of the glands of internal secretion, also known as the endocrines. This general law makes them the essential determiners of health and disease. It is important to realize the properties of catalysts in general as fundamental controllers of chemical reactions to grasp the meaning of the dominating influence of the hormones of the ductless glands as biocatalysts in the immense chemical factory which is the bodymind. Also, since they are effective in the tiniest quantities, individual variations in their functioning, due to slight differences in the organs producing them, have a tremendous influence in determining the different varieties of metabolism encountered in distinctive types of human beings.

The Action of Catalysts on Substrates

Now, in addition to the catalysts and their variations in the blood and tissues, it is necessary to consider differences in the amounts of the special substances in the cells and organs upon which the catalysts act. These substances are called the 'substrates' of the catalysts. The catalytic enzymes and hormones affect the specific chemical compounds found in and characteristic of the tissues, such as the skin and its underlying tissues, the muscles, the bones, the bone marrow and teeth, the nerves and nerve cells including the brain, and the different internal organs, the heart and lungs, the liver and spleen, stomach and intestines, kidneys and sex glands. All these are made of the living substance familiarly designated 'protoplasm' which Thomas Huxley named the 'physical basis of life'.

Protoplasms of different tissues and organs vary extremely in their chemical composition. And it is the variation in their chemical composition which makes them different. That is, skin, for instance, is so different from kidney because characteristic substances are present in the skin which are not present in the kidney, and vice versa. Skin, for instance, contains keratin and kidney large amounts of uric acid.

These tissue characteristic chemicals, the investigation of which constitutes one of the major tasks of biochemistry, are

the reagents for the catalysts. The catalysts cause things to happen between them. Catalysts are constantly resident and generated within cells. But they are also most importantly recruited from without by way of the blood or lymph stream from the glands of internal secretion.

All cells contain certain substances in common, just as all foods contain about the same substances in common. Universal are water and salt. Then there are always found the fats and their relatives which make up the group included under the name of the lipins. Also there occur commonly the sugars and starches comprising the carbohydrates. Besides, there are regularly various mineral salts and vitamins. And as a residue, a miscellaneous collection called the extractives.

But in addition to these compounds, common to all cells, are found substances more or less peculiar to the tissue. Such is melanin, the pigment substance of the skin, or creatin, which occurs characteristically in muscles, or the haemoglobin of bone marrow and blood. Differences in the quantities of these in various individuals have great significance for research into the reasons for differences in human beings.

The Functions of Foods

From this angle of vision, then, that tissues consist of special substances, which are either the substrates or catalysts of chemical reactions in cells, we obtain the insight that the different foods and their digestive products function in two ways: *either to replace and re-form the substrates, or to replace and re-form the catalysts.*

Either the replacement or catalytic uses of foods are the functions to consider in prescribing a diet fitted to the individuality of anyone interested in maximal health and efficiency. Now the replacement needs are not the same, and in the nature of things cannot be the same, for all human beings. For human beings differ in their replacement needs as much as in their catalytic needs.

Moreover, there is a relation between the type of an individual's psychology and the type of his food replacement and catalytic needs. The simplest way to test this principle is to watch the changes in the behaviour of an individual nourished upon different kinds of foods and diets. The results can be checked and correlated with his

reports of concomitant variations in his conscious introspective life.

The Importance of Individual Differences

In the light of these principles, it becomes once more manifest how absurd is the conception of a 'normal diet'. Individuals differ as regards what they need to replenish each and all of the constituents of their tissues, as regards water, as regards proteins, as regards fats, as regards carbohydrates, and as regards mineral salts and vitamins.

It is true that there is a 'normal diet' in the sense of a diet on which the individual, like the rest of his racial or family group, 'gets along'. Such a diet by no means coincides with what a chemical glandular analysis of his personality reveals as what he needs to function dynamically, optimally, and most efficiently. Every diet should be based upon the individual chemistry. It should be planned not only to prevent relative *starvation* because of deficiency of certain food elements. It should also be designed *to eliminate the gradual clogging and consequent degeneration of tissues due to an excess of certain substances, which the individual is not equipped to handle properly because of the way his endocrine glands function.*

As soon as one realizes the universality of this great principle of individual chemical variability (which once stated seems to be the tritest of truisms), it also becomes possible to appreciate the reasons for conflicts between different scientific workers concerning the amounts of the different foods to be included in a so-called 'normal diet'. The classic instance is the controversy concerning the amount of protein to be taken during twenty-four hours. There are two opposed scientific sects concerning the amount of protein to be consumed daily. One school, which might be called the Voit-Rubner denomination, holds that a man engaged in the average amount of daily physical exertion needs from one hundred to one hundred and twenty-five grammes a day. The other group, which might be called the Chittenden-Hindhede doctrine, holds that only about one third to one fourth as much is needed.

The controversy has not yet been decided in any final way because each side has been unconsciously influenced by its own needs to limit its investigations to its own type of individual. Each side is, in effect, pleading for its own con-

stitutional tendencies. As soon as it is realized that a high protein diet may be desirable for one individual because he is built to handle himself and to function optimally on it, while another may be constructed to metabolize adequately a much smaller amount of protein, and to live efficiently on it, the controversy is seen to be non-existent.

Now the question arises: What are the causes of constitutional differences in food requirements? Why is it that Jack Spratt can eat no fat and his wife can eat no lean? To ask that question is to encounter the core of our problem. In the present state of our knowledge, three reasons emerge outstandingly to explain these individual differences. They consist of differences in intestinal ability to absorb food, in the metabolic ability to assimilate and burn foods, and in the capacity of the organs of excretion to eliminate them.

The Intestinal Factor

Conditions in the intestinal tract, such as its acidity or alkalinity, its content of lime, phosphorus, ferments and bacteria, bile and fatty acids, vary the absorption of different products of digestion. Absorption depends largely upon the physiological activity of the cells of the intestinal lining. These cells are exquisitely sensitive to the chemistry of the blood and the psychology of the individual, especially the emotions.

The intestines play their part in every emotion. Their secretions as well as their powers of absorption change with every emotion. A fairly well-balanced, evenly dispositioned person will have one type of absorption, while another, with ever-changing emotions, will have an entirely different type. To measure the type of absorption, a determination of the chemistry of the blood can be made before and after taking of nutriment. A chart of the character of the rise of the nutrients in the blood as they are absorbed is thus obtainable.

This intestinal factor has to be considered, for instance, in the treatment of thyroid disturbances. Some people develop goitres in spite of an adequate intake of iodine in their food. Some difficulty in absorption interferes with the proper assimilation of iodine. When such individuals are given iodine injections or a diet which modifies favourably the intestinal ability to absorb iodine, remarkable improvement in the goitres and in the accompanying symptoms occur.

Similarly, disturbances of the parathyroid glands may occur because intestinal conditions prevent an adequate absorption of calcium and phosphorus. That is why it is not enough to know that an individual does partake of all the desirable foods: it is also necessary to know how he is absorbing them from the intestinal tract. Much water may pass through a sieve, but it takes a sponge to retain it. The intestinal sponge varies from individual to individual.

From the practical standpoint of treatment, certain puzzles of therapy are completely solved, once this intestinal differentiation of people is considered. A woman who had become dull, rather slow in her movements, with poor memory, and constant somnolence, together with loss of hair and perspiration, was diagnosed thyroid deficiency, with a basal metabolism of minus thirty. She showed all the characteristic stigmata of thyroid deficiency. Yet thyroid given by mouth in doses five times the usual dose produced practically no effect. When given injections of thyreoglobulin and thyroxin, she responded at once.

A man who developed the weakness and typical lemon-yellow colour of pernicious anaemia, together with loss of ability to concentrate and attend to his affairs, failed to respond favourably to the incorporation of large amounts of liver and liver extract in his daily diet. He seemed to be becoming progressively worse and there was no improvement in his blood picture. When he was given injections of a soluble liver extract, his condition changed markedly for the better in a week, and in a month he was a different person, with a return of his ability to carry on his business affairs.

The Metabolic Range

The second factor is the *ability of the bodymind to metabolize*, that is, to use the nutrients in accordance with its needs, to change and burn them, meanwhile extracting energy. This phase of metabolism, which is the destructive phase, is also described as the catabolic phase. The destructive or catabolic phase is the opposite of the constructive phase, which is the anabolic phase or the capacity to use foods as building stones in making new tissue.

The capacity to anabolize and the capacity to catabolize, taken together, are the capacity to metabolize. This metabolizing, the ability to maintain a progressive chemistry which

keeps the bodymind a going concern, differs in different human beings. They represent the *metabolic limitations* of personality. They govern the amount of nutriments that can be taken up from the blood by the cells. The anabolic and catabolic tendencies are by far the most important factors in the production of individual types of bodymind chemistry and varieties of metabolism.

This metabolic factor can be measured by determining the chemistry of the blood under basal conditions. Basal conditions are assumed to be present after a night's rest, with the blood examined on a fasting stomach in the morning, provided the food has been as usual for several preceding days. Another way to study it is to observe the effect of injections of hormones upon the blood chemistry and the basal metabolism. For example, the amount of sugar in the blood, under basal conditions, is a measure of the amount of sugar in all the cells of the body, the blood itself being a tissue in equilibrium with the other tissues. The amount of sugar which can be assimilated by a muscle is dependent, all other things being equal, upon the amount of adrenal hormones, internal secretions of the adrenal glands within its cells, and the amount of insulin, the sugar-burning hormone, product of the endocrine glands of the pancreas. The effect upon the blood sugar of an injection of adrenalin or an injection of insulin provides much valuable information. The same principles apply to the amount of uric acid, phosphate, calcium, fat, iron, and so on.

Blood chemistry of our time is an amazing achievement, undreamed of a generation ago. For quite accurate determinations of the different chemical substances dissolved in the blood plasma are possible with very small quantities of blood. Indeed, by a determination of the energy metabolism and the blood chemistry, first under basal conditions and then after partaking of food, a remarkable insight may be obtained into the peculiarities of the individual chemical machine. Secondarily, a most profound understanding of his reactions to his world, which constitute his personality, is available. Such insight is an extremely valuable addition to the information on character obtainable by all other methods, physiological, psychological, or psycho-analytical, and should regularly precede them.

Because the glands of internal secretions dominate the

chemical constitution of cells as well as the reactions occurring within them, it is possible to predict much concerning the chemistry of the blood and the metabolism in any particular individual from a clinical examination of his endocrine glands.

In conditions of thyroid deficiency, one may predict that the basal metabolism may be from 20 to 40 per cent below normal and that the iodine content of the blood will be decreased. On the other hand, in the condition of hyperthyroidism, as may be diagnosed from the presence of a rapid heart, nervousness, excessive perspiration, and loss of weight, one may predict an increased metabolism which may be from 20 to 100 per cent above normal and at the same time an increased iodine content of the blood. In the condition of chronic parathyroid deficiency, which may also manifest itself by nervousness and insomnia, the respiratory metabolism, one may predict, will range within the usual upper and lower normal limits, but there will be a deficiency of lime in the blood and increase of the phosphate. In conditions of deficiency of the adrenal glands, one may predict a lowered content of sugar in the blood, with a tendency to acidosis or acid intoxication.

In all sorts of disturbances of glandular deficiency or excessive function, typical combinations of pictures in the metabolism and the blood chemistry may be predicted and checked in relation to the clinical diagnosis as revealed by careful physical examination and history-taking.

The Eliminative Factor

The third limitation in the metabolism of food is that of excretion or elimination : that is, the ability of the cells and tissues to rid themselves of chemical waste products, the end stages of metabolism, known as metabolites. If the organs of excretion, such as skin, the kidneys, and lungs, are not functioning properly, the blood cannot excrete substances like carbon dioxide, the end product of carbon metabolism, urea, the end product of nitrogen metabolism, sulphate, the end product of sulphur metabolism, they will naturally accumulate in the blood. As a result, food will simply add to the burden of the blood and tissues, and the body attempts to limit the assimilation accordingly. For the cells are very sensitive to variations in the chemistry of the blood. Yet they may fail, and waste products do accumulate, to achieve

finally a poisoning or degeneration of the very tissues which have produced them.

To measure excretion, the chemistry of the blood can be compared with the chemistry of the urine. Normally there is a certain ratio between the substances in the blood and the same substances in the urine. If there is interference with excretion, either in the way of not enough excretion or too much, the ratio is disturbed in one direction or another. Thus, in Bright's disease, the urea ratio is disturbed, there being too much in the blood (urea retention). In gout there is *uric acid* retention. By careful analysis the cause of retention or abnormal excretion can be determined.

Furthermore, analysis of the blood will show abnormal figures for the various constituents as they are retained. Thus an increase of the calcium content may be traced to a deficient action of the kidneys (eliminative factor), as opposed to an excess of calcium due to overaction of the parathyroid glands (metabolic factor).

In certain disturbances of the glands of internal secretion, the eliminative factor may play a decisive role. Certain disturbances of character, for instance, have been noticed in some women as they approach the menstrual period. These disturbances have a remarkable cyclical quality. The woman is apparently well until about a week or ten days before the onset of menstruation. Then she becomes highly excitable, irritable, suspicious, and at times hysterical. This condition has been named ' premenstrual hypertension ' by Frank. It becomes worse until the period begins and then the woman returns to her previous approximately normal state. Such individuals have often been subjected to several kinds of mental treatment, including psycho-analysis. Careful examination has shown that what happens in these women is an increasing concentration of the primary sex hormone, known as theelin; in their blood which the kidney fails to excrete or eliminate properly as it should. If measures are prescribed to stimulate the kidneys and intestines to increased elimination during the week or ten days before the period, the premenstrual hypertension no longer occurs. Injections of the internal secretion of the corpus luteum, which facilitates the excretion of this internal secretion of the ovary, will also bring about the same result.

Case history : This was a girl of eighteen, who, though she

showed a fair degree of development of the secondary sex characteristics, which placed her as fairly normal sexually as regards characteristics of physique, complained that for about two years there had been no menstrual periods. Also, that during this period, she had lost all sex interest and no cyclic variation in her libido during the month. She did have some signs of a monthly variation in the size and sensations of the breasts. Examination of the blood showed that there was an absence of the characteristic accumulation of the ovarian hormone which should occur during the last two weeks of the monthly cycle. On the other hand, the urine showed an excess of this ovarian hormone and an accompanying increase of the creatinine which has been found to increase in proportion to the increase in ovarian hormone. The only explanation possible of this condition was that the kidneys were abnormally permeable to the hormone in this girl, and were eliminating it as fast as it entered the blood. Treatment with the beta hormone of the post-pituitary changed the permeability of the kidneys, so that it was possible for the blood to accumulate the hormone, resulted in a restoration of the periods, and a return of the normal sexual character.

The Dietetic Treatment of Character

Under the usual conditions of everyday life, when an individual presents no signs of organic disease, and his mental reactions are those ordinarily characteristic of him—when he is, as people say, *himself*—the important factor limiting the assimilation of food is the metabolic limitation.

Anabolism and catabolism, the building-up and the breaking-down of the living cells, are the great phases of the metabolic process. They explain individual chemical differences in people. The rate of anabolism and the rate of catabolism determine the limits of assimilation of any particular food for any particular cell. There is an anabolic-catabolic ratio—construction keeping pace with destruction—which results in normal maintenance. This ratio, then, determines the amount of any chemical substance needed for replacement. If there is a lack of it, or an excess of it, we have the phenomenon that so completely demonstrates the unity of bodymind, the special desires and aversions of the appetite which correspond to the chemical needs.

When specific disturbances of metabolism involving one

or another of the three limiting factors may be associated with specific disturbances of character and personality, a specific dietetic treatment of character becomes possible. In any disturbance of character, the balance and ratio of the food substances and endocrine products being supplied to the brain and the nervous system should be considered.

Character is a matter of balanced, interlinked reactions of all the parts of the bodymind. It involves, first of all, the building stones supplied by food, which might be compared to the substrates of a chemical reaction. Secondarily, it concerns the regulators of growths and development, the endocrine glands and their hormones, which might be compared to the catalysts of a chemical reaction. The end products of the chemical reaction—the products of metabolism, which make and unmake character—are then dependent on the nature, amounts, and relations of the substrates and catalysts. In practice this means that character is contingent upon the nature, amounts, and relations of the food constituents and internal secretions.

Different organs are not equivalent as regards their needs of different food substances and hormones. For example, there is a specific need of the peripheral nerves for Vitamin B. Peripheral neuritis appears in Vitamin B deficiency when there is as yet no symptoms of pathology in any other tissue.

A specific dietetic, growth, metabolic and endocrine mechanism exists for each type of character. And the different organs composing the personality are not equivalent as regards their needs of different foods and of different internal secretions. For instance, there is a specific relation of the uterus and the vagina to the internal secretions of the ovary. Though these secretions affect other organs, the uterus and vagina are more exquisitely sensitized to them and much more dependent on them. These differing needs of different organs may be worked out by means of detailed studies of the reaction of the various tissues to specific endocrine deficiencies or hyperfunctions and definite food deficiencies and excesses.

The chemical differences in individuals are the most fundamental, the most important, and the most far-reaching in their effects upon character and personality. The most hopeful fact known to-day is that these chemical differences in human beings are controllable through foods and treatment of the ductless glands.

Richet, the great French student of blood reactions, was one of the first to emphasize the tremendous importance of individual blood differences : ‘ Every illness,’ he wrote, ‘ every intoxication has caused the formation, perhaps the destruction, of a certain substance in the blood and has left its natural trace—a trace which is not effaced by the years ! Just as there is a psychological memory—facts which are represented to consciousness—so there is a memory in the blood of all preceding reactions of it. As these reactions differ in each person in intensity, quantity, and duration, it follows that each person differs from every other in the chemical properties of his blood.’

CHAPTER VI

WATER, VEGETARIANS, AND FLESH-EATERS

WATER, living water, the water of the ocean, of clouds, of protoplasm, is something to which temples should be dedicated and daily rites of worship offered. For it is a substance like no other on the earth or in the heavens.

Thales, that Greek philosopher who was one of the first to display a modern type of mind in his speculations, made water the aboriginal source of all things. From water into water—that was his summary of the history of creation and the evolution of the universe. Aristotle made it one of the four elements out of which all entities were composed, the others being earth, air, and fire. And although chemical analysis has destroyed for ever the idea that it is an element, seeing that it is compounded of oxygen and hydrogen, it has by no means been displaced by any other substance as the most universal, the most essential, the most available of all foods.

Water has properties which have intrigued the physicist, the chemist, the geologist, and the biologist. It exists as a gas in the atmosphere, as a liquid of the oceans and seas which constitute almost three-fourths of the surface of the earth, and as a solvent interpenetrating the solid earth nearly everywhere. It is by no means rare and yet it is unique in nearly all of its powers. It can take up a great deal of heat before its temperature is significantly raised; it is a most effective insulator against electricity, and yet a most efficient conductor of it when salts are dissolved in it; and as a solvent, nothing can compare with it. As such it deserves poems and paeans.

Without water, life would be impossible. All the properties of life are possible only because of the properties of water. Because of its peculiar capacity to store heat, as well as to

conduct it, it makes it impossible for the living protoplasm to set itself on fire in the course of its combustions, a necessity for the provision of energy. Because of its capacity to become a simple conductor of electricity in the presence of salts, it is possible for protoplasm to canalize and pattern its displays of energy and so prevent an anarchic chaos of explosions that would destroy it. Because of its unique solvent powers and surface tension, the creation of blood became possible. And without blood there never could have been higher evolution of protoplasm.

Of protoplasm, water forms about 70 to 90 per cent. We are all waterlogged sponges, for we carry water to the limit of our capacity. Continually our cells, as living sponges, lose water by evaporation through skin and lungs, and by excretion through kidneys and intestines.

Chemical Needs and Special Appetites

Now, the close relationship between body and mind is well illustrated by a study of the metabolism of water as an essential foodstuff. If the replacement of the lost water is not adequate, there follows that vague, indefinite sensation-craving called ' thirst '. It is a registration by the brain of the chemical conditions of the cells and tissues. First, this is translated into consciousness as a vague local feeling in the tongue, mouth, and throat. Finally it drives the organism to seek water to abolish the craving which may become an emotion of agony. If prolonged and unsatisfied, it becomes an obsession of consciousness.

But water is not the only determinant of thirst. The mineral salts, and in particular sodium chloride (chief constituent of ordinary table salt), also play a determining role in its genesis. Though these mineral salts perform as important functions in the body, they differ from the energy-producing foods, proteins, carbohydrates, fats, and lipins. They are not burned into metabolites, as are the latter, but are excreted as themselves. The salt comes in as salt and goes out as salt.

Sodium chloride dissolved in water or protoplasm breaks up into an ion of sodium positively charged with electricity and an ion of chlorine negatively charged. Sometimes these are called positive and negative electrolytes. Being elements they cannot be further decomposed. They travel as so-called

ions in the blood and cells. Through the kidneys, they are finally excreted as sodium and chloride.

Now, it takes a certain amount of water to dissolve salt. Also it takes a definite amount of salt to maintain a normal concentration of water; at least, that which is optimal for the blood and the tissues. This is the physiological concentration.

Salt, when dissolved at approximately the physiological concentration, is known as physiological saline. At the body temperature, this physiological salt solution may be injected into the blood without damaging the red and white cells floating in it. But if the solutions are not physiological in concentration, the red and white cells are harmed. They have to adapt themselves to the foreign medium by losing water or taking it up. This latter depends upon whether the injected salt solution is weaker or stronger in salt than themselves.

Consequently, thirst is dependent, not only upon the amount of water, but also upon the amount of salt, in the tissues. If there is too much salt, we crave water as much as if we were water-starved. Thirst is, then, a matter of *water-salt balance*; in other words, it is an expression of the individual's limit of assimilation with respect to salt and water.

The metabolic catalysts controlling the water-salt balance of the cells are thyroxin and pituitrin. These are the hormones of the thyroid and one of the hormones of the post-pituitary gland. The latter was discovered by following a clinical clue. The lead was the discovery that a crude extract of the post-pituitary gland (pituitrin) was a specific in relieving the terrific thirst characteristic of a disease of water metabolism, diabetes insipidus.

Varieties of Metabolism

Metabolism, the chemical changes of the bodymind, occurs as different foods are absorbed and utilized. The food which the individual has the least capacity to use may determine the kind of metabolism characteristic of him. The weakest link in the chain of chemical events then becomes the strongest. Or, to put it another way, the pacemaker in any metabolism is the food which lags behind the others in rate of utilization. The others have to keep step with it.

On the other hand, certain foods may be preferentially

consumed. So the one which the individual has the greatest capacity to utilize may come to dominate his metabolism. Then the chemical reactions involving other foods must adjust themselves to it. This is true of certain people who can use protein more easily than sugar, which reverses the usual state of affairs. Such a food becomes central in the chemical history of their metabolism.

It is, therefore, necessary to look upon each person's metabolism, and consequently his diet, as centred around some special aspect of his chemical needs and capacities. From this point of view, we may have any number of types : water-centred, protein-centred, sugar-centred, fat-centred, or, specifically, vitamin-centred. The particular substance which is central represents the special strength or special weakness of the metabolic budget.

The Water-centred Type of Individuality

Each hour of the day, the skin through perspiration, the lungs through the moisture of expired air, and the kidneys through the urine, lose water. This water loss has to be compensated for by the intake. Now, a certain amount of water is formed by the cells when they burn food. Two atoms of hydrogen combine with oxygen, in the combustion, to form the oxide called water. Fat when burned gives the most water. In fact, more water is produced than the weight of the original fat. For one gramme of fat produces one and one-tenth grammes of water. Sugar when burned gives the least. One gramme of sugar burns into three-fifths of a gramme of water.

In addition, there is combined water. This is held in cells because of their colloid nature. It is held in a sponge-like condition by protein, sugar, or fat. This form of it is also freed when one of the combustible foods is burned. Much water is thus liberated during metabolism. One gramme of protein, for instance, releases four grammes of such combined water, protein being most avaricious for water.

Certain animals possessing no sweat glands except in the jaw can live without water, because water stored in the tissues is either liberated or manufactured as metabolism continues. Man, however, perspires freely and easily, loses much water and needs constant replenishment for his cells.

When an individual is water-starved, the first signs to

manifest themselves are a dryness of the skin, lips, mucous membranes, and scalp. The condition in the scalp is a form of scaliness known as seborrhoea. The greatest danger in loss of water or dehydration is degeneration of the kidneys. It makes them unable to excrete the acid products of metabolism. The resulting acid self-poisoning has disastrous and ultimately fatal effects on the nervous system. A tendency to hallucinate appears. Particularly is there the vision of a source of water supply; the classic mirage of the oasis, which is the perfect example of the wish being father not only to the thought, but also to the reality.

Hydrol, or water in the liquid form, is an absolute necessity to life. No man has enough of a water storage to last him for more than a few days. But there is a limit to the amount of water he needs and therefore should take. Notwithstanding common advice to drink as much as possible, it is almost as disastrous to suffer from water-poisoning or hydrol-intoxication by intake of an excess of water as to suffer from a deficiency of it.

It is interesting that tissues vary considerably in their water content. Blood is 90 per cent water, the brain 85 per cent, the liver (solid organ though it is), 75 per cent water. Even bone, which is 125 per cent stronger than cast iron, consists of 40 per cent water. All of which bears out the tremendous physical and chemical importance of water for life. Water is the best solvent of solvents, and the stream of life always functions in solutions.

Water also has a unique capacity to take up and store energy, particularly heat, without changing essentially in its physical state. Hence, life in water can burn without destroying itself in its own fire.

Yet water is by no means the panacea it has been contended by some of its panegyrists. There are individuals who have a curious capacity to absorb and store water, and then quickly to lose it. These are the water-unstable individuals, and their disease is a tendency to oedema. And there are those who cannot store water even though they have the most torturing desire for it—those affected with diabetes insipidus.

Diabetes insipidus is a disease in which the individual is unable to maintain proper balance between the amount of water he takes in and the amount of water he puts out. Or, in other words, there is a negative water balance.

Based upon the diseases of water metabolism which are called oedema and diabetes insipidus which are the extremes of function, and the concepts inherent in the present knowledge of these diseases, it is possible to work out the normal water-centred types of metabolism.

The Water Plus or Superhydrated Person

The superhydrate is one who has a tendency to retain water excessively. He tends to saturate his tissues with water. Consequently, he retains salts, such as the chlorides, because water alone cannot be retained in or between the cells unless combined with salt. This maintains the normal, physiological concentration, which prevents the cells from bursting and losing their contents. This latter happens when they are exposed to pure water.

What such a person, therefore, retains is salt water. The water-saturated individual is one whose tissues are soaked in this physiological saline to the limit of his capacity. Now, what is characteristic of these individuals ? In the first place, they tend to look bloated, as they are, with water. They are sometimes described as plethoric when they also have a high colour. But others may be pale. This is because of anaemia or because of the dilution of the red cells due to the excessive water in the blood.

Also characteristic is the tendency to gain or lose weight easily and quickly. This occurs because water can be lost in the body with great facility through the four different channels—kidneys, intestines, skin, and lungs. As a result, striking changes in the appearance and expression are engendered. Such variation is often associated with the nervous state of the individual. More water is retained when he is worried or tired and less when he is rested and relatively undisturbed.

Examples of the superhydrated type are frequently seen among children, in whom it manifests itself by the symptoms and signs of what is known as the exudative diathesis. In these infants the instability of the water metabolism is obvious. Their skins may become red and scaly or even swell in blisters of water which break and leave exposed areas diagnosed as eczema. Their skins exude the water this way, which is the basis for the name of the tendency. The German pediatrist, Czerny, said that these children have a hydropic constitution.

He associated the type of constitution (metabolism) with a tendency to various diseases of the skin and mucous membranes and traits of personality.

These conditions may well be associated with superhydration of the nervous system. Although there is no direct way of measuring the water content of the nerve cells, there is an indirect method; namely, determine the response of the nervous system to a limitation of the water intake, while all other factors are being held constant. That superhydration may be connected with an increased and even an explosive irritability of the nervous system is shown by recent discoveries concerning that anciently abhorred and mysterious disease, epilepsy. Certain cases of epilepsy in children are improved and sometimes even cured by limiting their water supply. Putting these children on an acid-forming diet dehydrates the brain and stops their attacks.

Superhydration of the nervous system may also present itself in certain children in a less degree in the hyperactivity causing them to be referred to as 'wonder children'. In addition to presenting the physical and chemical signs of the exudative diathesis, they also have an abnormal psychology and are frequently gifted in some artistic way—most often in music.

But the endocrine basis is the most interesting. Water metabolism may be said to be primarily regulated by two glands: the thyroid and the post-pituitary. While the thyroid favours the elimination of water, the post-pituitary facilitates the retention. It is easy to see, then, that an individual's water requirement, all other things being equal, will be determined by the balance between these two glands.

A hyperthyroid individual will lose water freely and easily, and therefore needs much. A thyroid deficient loses little, and therefore needs relatively less.

A hyper-post-pituitary person retains water easily, and therefore requires much less. The deficient in the post-pituitary demands much more because his water leaves him soon after it reaches his cells. He is unable to absorb it, as in diabetes insipidus.

Behind the exudative diatheses there is probably an unstable functioning of the thyroid gland. The primary action of thyroxin and thyreoglobulin (the internal secretions of the thyroid) is upon the nitrogen exchanges of the body. More

particularly it affects the amino-acid metabolism. So the hydration of the tissues is tied up with the intensity of the nitrogenous, as well as the salt, chemistries of the cells.

When the thyroid deficiency is treated with thyroid preparations, water elimination is markedly accelerated. Accompanying it are the striking losses of weight that attest the action of the thyroid. Also in nephrosis, a degenerative disease of the kidneys, there is a marked retention of water. And thyroid will stimulate the excretion of tremendous quantities of water from the children who are afflicted with the oedema of this type of kidney disease.

Instability of the thyroid is associated with an instability of weight, due to rapid fluctuations of the water hunger of the protoplasm. Children showing the characteristics of the exudative diathesis have been proved to have a higher metabolism than the normal. They consume more oxygen and produce more carbon dioxide. This is consistent with the view that they are unstable hyperthyroid people.

The Water Minus or Dehydrated Individual

Children, because they are growing rapidly, need three times as much water as adults. They have a well-functioning thymus which is necessary for proper growth. The thymus facilitates the retention of water. Thymus extracts cause colloids to take up more water. Consequently, children suffer much more acutely than adults when deprived of enough water.

The blood of the new-born contains much less water than that of the adult, but their tissues have more. Indeed, there is a constant diminution of the water content of the central nervous system from birth to old age. So susceptible is the new-born to water deprivation that a few tablespoons of water may relieve the so-called water fever of an infant. An injection of a drop or two of post-pituitary extract will also cause it to retain water and cure the fever.

Through the study of diabetes insipidus, many interesting discoveries have been made of the relation of the post-pituitary to the water metabolism and the water needs of the ordinary so-called normal individual. In this disease the quantity of urine excreted per twenty-four hours may be twenty litres or quarts, which is about 1,000 per cent greater than the average. It looks like water and has about the

same specific gravity. The body being unable to retain it, it soaks through the kidneys and is excreted almost as soon as it enters the blood. The afflicted, suffering from intolerable thirst, naturally craves water and keeps on drinking it. Meanwhile, the skin and mucous membranes become dry and parched. All the tissues, including the nervous system, present the stigmata of water starvation.

If this type of diabetic is not permitted to drink as much water as he wants, he becomes hysterical, almost maniacal. There is a loss of appetite, digestive disturbances, with headaches and nervousness. Nothing but water—no drug, medicament, food, or therapeutic procedure—could help him until the discovery of the efficacy of pituitrin.

It was the adventurous Spanish physician, Francisco, who found that a hypodermic injection of the pituitary extract would marvellously relieve the condition. After a half-hour, the individual becomes quite pale, due to a contraction of the blood vessels of the face. But the insatiable thirst disappears, as if slaked for ever. The excessive urine ceases. The amount for the twenty-four hours is only about a litre and a half or two, the average normal. The tissues of the skin and mucous membranes become less desiccated. He becomes calmer. But the effect is only temporary. At the end of twenty-four hours, another injection must be given. Otherwise the symptoms return. However, after a prolonged period of treatment a permanent cure may result. Or, at any rate, such marked improvement that only one-seventh of the original dose is required (Motzfeldt).

Recent work of English, American, German, and French biochemists, has shown quite conclusively that the post-pituitary gland produces three internal secretions. One, known as the hormone alpha, controls the contractions of the uterus during labour, as well as between menstrual periods. The second, the beta hormone, governs the sensitivity of the kidneys toward water and salt and regulates the ability of the bodymind to retain them. It has also been called the water-retaining hormone. The third, which might be called the gamma hormone, regulates the ability of the pigment-containing cells of the skin to contract. An injection of the beta hormone may cause the body to retain water that ordinarily would be eliminated quickly. And a series of injections may cause a definite permanent increase of weight, due to water

retention, even in normal individuals. It is the beta hormone which is effective in diabetes insipidus.

On the psychological side these individuals are characterized by a tendency to drowsiness and apathy, as well as neuropathic symptoms, particularly a plaintive hypochondriac disposition. Treatment with the pituitary extracts changes and benefits these complaints for the better, too. So the psychopaths, drinking much water and secreting much urine of a low specific gravity, should be placed on a diet of high water, low salt, and protein. Particularly if pituitary solution is administered at the same time, they will be much improved. Every complaint of drowsiness and apathy, combined with neurasthenia or psychasthenia, should be studied from this viewpoint. There are definite tests available to-day which reveal the state of function of the post-pituitary gland.

Available data on the relation of the post-pituitary to water metabolism suggest that the pituitary internal secretion passes directly into the nerve centres controlling water metabolism and thence into the cerebro-spinal fluid bathing all the brain and nerve cells. It also flows into the general circulation, reaching the kidneys, and there exerts an effect on water retention. The work of Motzfeldt has demonstrated the concurrence of the physical and psychological signs and symptoms which make possible depiction of this type of water-dehydrated-centred type of individual.

Two types of human beings are thus distinguishable by correlation of metabolic tendency and character traits in relation to water and salt. One is the waterlogged, superhydrated, describable chemically as ‘ plethoric ’ and emotionally as ‘ choleric ’. The other is the dehydrated or water-poor variety of human being, who may be characterized chemically as ‘ dried ’ and psychologically as ‘ neurotic-hypochondriac ’. They are connected with imbalances in the endocrine glands of the different types. These groups of water metabolism are always associated with salt disturbances which determine food cravings and mental and emotional attitudes of character.

The Need for Salt

We are all descendants of Venus, because like her we have come out of the sea. Indeed, we are so related to the sea that

we shall never get it out of our veins and arteries, for it is in our blood.

The chemical composition of human blood resembles the salt water of past ages of millions of years ago. The percentage of salts in human blood is the same as that of the sea water of to-day, as regards sodium, chlorine, potassium, and calcium. But the magnesium of human blood is much less than that found in the sea water of to-day. The magnesium has increased in the ocean's brine since the days when man's ancestors lived in it. The salts of human blood reflect the chemistry of the ancient ocean in which life first flourished.

Animals who live in salt water use it as blood is used by humans. They incorporate it in their bodies. Therefore, they contain various metals found in the sea, extracting from it various elements peculiar to themselves. When we eat food, we take into ourselves these different strange metals not ordinarily associated with foods. Lobsters and mussels have cobalt in their bodies. Nickel is found in molluscs. Both of these metals are probably important for the production of insulin in the pancreas.

Pasteur named these minute elements '*Les infiniment petits chimiques*'. It was to describe the action of these infinitesimally present, but infinitely powerful, substances which brought about such profound changes in biochemical systems, that the word 'catalysts' was coined.

Gabriel Bertrand, at the Pasteur Institute in Paris, has been working for years on the relation of these metals to the body-mind economy. He has made some most interesting findings as regards the presence and function of nickel and cobalt, for instance. He discovered a relation between these two metals and the endocrine function of the pancreas. To quote M. Bertrand : 'The experiments have shown that with certain preparations of insulin the simultaneous injection of a small quantity of nickel or of cobalt increases notably the quantity of sugar destroyed. We have made experiments upon dogs and rabbits and found in both cases an increase of the hypoglycemia of the insulin.'

He advocates in certain forms of diabetes the introduction into the general circulation of the patient of small quantities of nickel or of cobalt. In simple diabetes, excluding the consumptive type, he has tried in his experiments, first, the use of one metal alone, then the other alone, and then a

mixture of the two. The disease has been helped, ‘ sometimes even to the extent of the complete suppression of urinary sugar ’.

Oysters and clams contain copper, a valuable ingredient for the making of blood. The ascidians or sea squirts are familiar objects on rocky seashores. They occur often in large colonies sticking firmly to their stony habitat. They extract, out of the sea, the rare metal, vanadium. This is used at present in the making of an important steel alloy. It would be interesting if it were shown that this vanadium was necessary in the manufacture of hormones. Certain other marine organisms contain lead. If the human blood needs these different inorganic metallic salts, the importance of these marine animals as foods becomes obvious.

Sodium versus Potassium

The illustrious German philosopher-biochemist-physiologist, Bunge, pointed out that common table salt (sodium chloride) is unique among the foodstuffs : it is the only inorganic salt deliberately added to food. All the salts needed to maintain a balanced mineral ratio—the chlorides and iodides, the carbonates and phosphates of sodium and potassium, the calcium and magnesium, iron and copper and manganese compounds—are consumed in the fruits and vegetables, meats and cereals of the daily meals, without thought of adding more of them artificially. But the familiar table salt is sought and relished and its use has passed into proverbs the world over.

Even though large amounts of sodium and chlorine, obligatory constituent of all animal and plant cells, are present in all animal and vegetable foods, common salt is added. Why ? Why, some people would say glibly, to season the food, in order to bring out its flavour. There are other ways of seasoning food. Though it is true that food becomes unpalatable when salt is not added, it is only for those who have a definite need of salt that such an unsavoury taste develops.

Bunge pointed out that the craving for salt seemed to be conditioned by the herbivorous or carnivorous habits of human beings and animals. The ruminants and hoofed animals, who are accustomed to live upon vegetables and plants only, search for ‘ salt licks ’. They will risk their lives

trying to get salt from these salt rocks and pools. Hunters knowing this, prey upon them at these spots, and sometimes use salt as bait.

Beasts of prey, who live upon flesh, do not show any salt yen or instinct. Yen is the better word, for it is much like the craving for morphine of the morphinomaniac. It is the vegetarians who have the salt addiction. In the case of the domesticated animals, it is known that the herbivora—cows, sheep, and goats—are quite desirous of salt ; while the carnivorous dog and cat dislike salted food.

A whole series of facts about the salt habits of various peoples all over the globe confirm the generalization that flesh-eaters abhor, while vegetarians crave, salt. Hunters, fishermen, and carnivorous wandering tribes exhibit a disinclination for salt or salted food. The hunters' reaction to salt is best illustrated in Siberia. All parts of that country abound in salt lakes, salt rocks, and salt deposits. To the Siberians these areas are simply the places where flocks of reindeer visit to lick the salt. There the hunters wait for their kill and consume the meat with no thought of salt-seasoning it. If offered salt or salted food, they quickly show their dislike. Bunge pointed out that among the Greeks and the Romans animals were sacrificed to the gods without salt, but fruits of the earth were always offered with salt. Also he speaks of the remarkable fact that the Mosaic Law definitely ordered the Jews to accompany their vegetable offerings to the Lord with salt.

The Tudas of the Nilgiris of India, a pastoral people, live upon milk and buffalo meat, eat no vegetables, and are totally unacquainted with salt. The Kirghese, although surrounded by salt steppes, exist on milk and meat, and never touch salt. The Bedouins of Northern Africa feed upon meat and milk, and consider the addition of salt to food as ridiculous. The Bushmen of Southern Africa, who subsist by the chase, do likewise.

On the other hand, the negro races of the interior of Africa are agriculturists and consume much vegetable food. The classic quotation of Mungo Park is worth quoting. He is writing about the craving for salt of the Western Africans :

In the districts of the interior, salt is the greatest of delicacies. It strikes a European very strangely to observe a child sucking

a piece of rock salt as if it were sugar. I have frequently seen this done, although the poorer classes of inhabitants in the interior are so badly provided with this costly article that to say that a man eats salt with his meal is equivalent to saying that he is rich. I myself have found the scarcity of this natural product very trying. *Constant vegetable food causes a painful longing for salt that is quite indescribable.* On the coast of Sierra Leone the desire for salt was so keen among the negroes that they gave away wives, children, and everything that was dear to them in return for it.

Natural Vegetarians and Natural Flesh-Eaters

In this striking difference of salt craving between herbivora and carnivora, it was noted that a herbivorous animal receives, in its usual food, proportionately about the same amount of sodium chloride as a carnivorous animal. Each obtains from Nature about an equal amount. Yet it is the herbivora (vegetarians) who experience the yearning for salt addition to their diet. The salt addiction of these vegetarians, therefore, cannot be due to a simple deficiency of sodium chloride in their food.

The problem illustrates how a food craving may be due not simply to a deficiency, but to an *imbalance,* in a diet. For the outstanding difference between the vegetable and animal foods as regards mineral content lies in the fact that animal foods contain sodium and potassium in almost equal (balanced) proportions, while the vegetable foods contain an excess of potassium salts, and therefore represent an unbalanced sodium-potassium mixture.

Bunge proved conclusively that the vegetarian craving for salt was due to the excess of potassium salts in vegetable food. He carried out upon himself the experiments of adding an excess of potassium salt to his diet. By doing so he at once obtained an increased excretion of sodium in his urine, the amount corresponding to somewhat less than half of the ingested potassium. Potassium drives out sodium from the tissues. The cells, in turn, especially the nerves, respond with a cry for salt.

The sodium-potassium imbalance is brought about in vegetarians in the following way: There is an excess of sodium chloride in the blood normally. There is a much smaller quantity of potassium. Although sodium and potassium resemble one another remarkably in their physical and

chemical properties, potassium cannot replace sodium in the blood. This may be because potassium has a certain amount of radioactivity not possessed by sodium. The slightest increase of this radioactivity in the blood would tend to damage the cells irreparably.

The kidneys, sensitive recorders of the chemical composition of the blood, react promptly to any deviations from the normal in its mineral content. When an excess of potassium enters the circulation after the digestion of vegetable food, the sodium chloride of the blood reacts with the potassium compound to form a sodium compound and potassium chloride. This decreases the amount of sodium chloride in the blood. The new sodium compound is treated as a foreigner by the kidneys and promptly deported in the urine. To maintain a constant sodium chloride content of the blood, the tissues are depleted of their salt. This produces a deficiency of sodium, which finally registers in the consciousness of the animal a sense of need for salt that may become a painful craving. No better instance could be cited of the relation of consciousness of need to a profound chemical necessity of the body.

A majority of edible plants, tubers, fruits, and vegetables contain an excess of potassium over sodium salts. This is so of potato, for example. Rice is an exception in that it contains much sodium. This may have been very important for the history and development of the rice-eating races, such as the Hindus and the Chinese.

Bunge found a confirmation of his explanation of the occurrence of salt-eaters and salt-abstainers, corresponding to vegetarians and flesh-eaters, in the customs of a tribe of negroes living in the neighbourhood of Khartoum. These people discovered a plant which contains an excess of sodium over potassium salts. The plant belongs to the salt-wort or Salsola genus. They used the ash of this plant as an addition to their other vegetables. Thus providing a natural balance of added sodium to their regular potassium intake, they got along without salt.

The Difference between Carnivores and Herbivores

Now it can be asked: What is the relation of the salt balance to types of human beings, physically and psychologically? Natural vegetarians and natural carnivorous varieties

of human beings have been described by Goldthwaite, Bryant, Berman, and others. Their findings as regards the general traits of the two groups are contrasted in the following diagrams:

I. Dietary Tendencies of the Two Types

	Vegetarians	*Flesh-Eaters*
Food	Starches, greens, vegetables	Meats, greens, not enough vegetables
Carbohydrates	Favourite food	Least favoured food—easily cause gas formation
Fats	Normal diet	Easily cause fat indigestion
Proteins	Easily taken in excess	Normal diet
Alcohol	Light wine, and beer with low alcohol content if alcohol is used at all	Brandy or whisky and other distilled liquors with high alcohol content preferred
Sugar	Prefers sugar to alcohol	Prefers alcohol to sugar

II. Chemical Tendencies of the Two Types

Chemical	*Vegetarians*	*Flesh-Eaters*
Urine	Generally alkaline or neutral	Generally acid
Acidosis	Easily fatal; no formation of ammonia from proteins	Not easily fatal; ammonia formed in considerable amounts
Calcium	Considerable amounts in urine	Usually small amounts
Phosphates	Usually small amounts only	In urine large amounts
Urea	Usually small amounts only	In urine large amounts
Uric acid	Always present, but in traces only	Amount varies with diet; tends to be high
Indol	Usually absent in urine	Often in large amounts in urine
Metabolism	Low	High

III. Organ Tendencies

	Vegetarians	*Flesh-Eaters*
Diseases	Systemic changes, slow onset, quiet development	Acute onset, sudden psychosis, often violent
Lymphatic glands	Average	Frequently enlarged
Spleen	Average	Small or large
Tonsils	Small	Often large
Bones	Heavy	Light
Brain	Usually average	Large, rarely very small in relation to body weight
Mentality	Deductive, slow, persistent	Inductive, active, changeable

IV. Relation of the Two Types to the Endocrine Glands

Ductless Glands	*Vegetarians*	*Flesh-Eaters*
Sex	Small reproductive glands	Large reproductive organs
Pituitary	Larger, variable	Variations slight, smaller
Pancreas	Usually large	Usually small
Parathyroid	Calcium balance normal	Tetany not infrequent
Thymus	Normal or large	Usually deficient, may be very large
Thyroid	Tendency to goitre due to deficiency of thyroid function	Tendency to goitre due to overfunction of the thyroid
Adrenals	Tends to enlarge, especially the cortex	Generally small, deficiency frequent

These are striking differences naturally characteristic only of extremes of the types. They represent opposite poles of the sodium-potassium balance. They are related to the chloride influence upon water metabolism. Hydrophiles and hydrophobes, salophiles and salophobes, vegetarians and carnivores—these varieties of human beings may be distinguished by the study of their individual personal characteristics, as well as by analysis of the chemistry of the blood and tissues. They are the ones to consider first when an attempt is to

be made to control metabolism from the psychological point of view and for any therapy. Salt, meat, and water may be used to modify considerably the function of the ductless glands, either to rest them or to stimulate them. By corresponding changes in the water content of the brain and nervous system, character and behaviour may be affected for better or for worse.

CHAPTER VII

LIME AND THE NEUROTIC CONSTITUTION

ONE of the most interesting and important of contemporary phenomena is the spread of 'nerves', 'nervousness', and 'neurotics'. Many reasons can be and have been assigned as the cause for the steadily increasing incidence of nervously disturbed individuals in America. They explain the continued success of new religions in the country, including the pseudo-scientific religions, like psycho-analysis and behaviourism. These people, aware of their nerves, who should be unconscious of them, rush for assistance from one new creed to another, or a revival of the older mysteries.

Now, by the application of the bodymind viewpoint to the problems of these neurotics, a real advance is possible and has been made in the understanding and treatment of them. Something of the fundamental nature of the individual is at fault, it is beginning to be realized. In one large group of them, at any rate, this fundamental something has to do with a disturbance of calcium metabolism in the bodymind.

In accordance with the trend of the times, the most recent researches show which way we are moving in our attitude toward these matters. In 1923, Berman separated the internal secretion of the parathyroid glands in a solution which he proved could affect and regulate the calcium metabolism of normal as well as abnormal animals. He then applied his extract to the treatment of 'nervous'—that is, neurotic—children and adults, who presented evidence of defective calcium chemistry, and who consequently were calcium-poor. They responded satisfactorily, with a clearing of their symptoms, and a restoration of a normal healthy general mood, freed of their miasma of neuroticism. He reported his successful results in 1925 and 1926. Subsequently, a number of

observers, one of the earliest being Florence Mateer and the latest being Donald Laird, have supplemented his findings by their publications concerning the management of nervous children by various measures taken to influence calcium metabolism.

As neurotic children grow into neurotic adults, one of the basic causes of their tendency to neurosis seems now definitely established. The dominant factor in its production is chemical. Neurotic complexes, conditionings, and fetishes find root in people whose nervous systems are calcium-starved.

Laird's findings are the most recently reported. He made observations upon fifty-three obviously nervous children in three grades of three elementary schools of Rome, New York. They were selected by their teachers as being the most nervous children in their classes. Yet they were not suffering from any organic disease, and were apparently as well fed and healthy as any of the other children. As far as the ordinary standards of height and weight were concerned, they were normal. But they were by no means normal, for, when tested, they showed a number of the characteristics of nervous instability. These nervous traits, thirty-four in number, were rated according to the scale of Olsen, by the teachers. Percentages, representing the degree of manifestation of each nervous trait, could thus be attained as the final score of nervousness for the particular child.

Three groups were made of these nervous children. One group of ten children were kept as a control group, receiving no dietetic treatment. They were, though, allowed to leave the classroom to play with special toys for ten minutes. A second group of seventeen received a half-pint of milk for five days each week at 9.30 a.m. The third group of twenty-one were fed the half-pint of milk plus a predigested food concentrate containing much calcium, phosphorus, Vitamin D, but consisting mostly of maltose and lactose which facilitate the absorption of calcium from the intestinal tract. It was flavoured with cocoa and easy to take.

After two weeks the control group showed an improvement of a little over 2 per cent. The milk group showed an improvement of a little over 8 per cent, while the third group, fed a really high calcium diet, exhibited a change for the better of over 15 per cent. The net average gain of the special lime-fed group was almost twice that of those given

milk alone. Three of the twenty-three in the special lime group failed to gain satisfactorily, but about half of those who took the extra milk furnished no evidence of improvement. In other words, 85 per cent of the nervous children were markedly improved in a short time by a diet rich in lime.

Laird describes the detailed data of a boy named William, aged nine. On the Olsen scale of nervous traits he had a score of 129. The score for normal children of his age is 67·5. By feeding him for two weeks with the milk plus the extra lime his score changed from 129 to 68, which is about what it should be. Before treatment was begun, the boy was rated as follows:

1. Absent-minded or abstracted
2. Difficulty in keeping at a task until finished
3. Extremely slow in thinking and very illogical
4. Mentally lethargic and unconcerned about things
5. Sloven in appearance and repulsive in bearing and physique
6. Weak in competing with others
7. Lacking in ordinary endurance
8. Insensitive to social feeling
9. Slow to accept new customs
10. Servile, unemotional and generally dispirited
11. Aggravating, cruel and impulsive
12. Acting on the spur of the moment

After two weeks, this is how he rated:

1. Less abstracted or absent-minded
2. Attention adequately sustained
3. Thinks with ordinary speed
4. Moderately careful in thinking
5. Displays ordinary curiosity, mental activity, interest
6. Physique and bearing not noticeable
7. Can hold his own against others
8. Moves with average speed
9. Socially more conscious and conforming
10. Emotions aroused much more slowly
11. Ordinarily friendly, cordial and open-minded
12. Acts with reasonable care

A sex difference and an age difference were found in the results. Children aged nine to twelve tended to show more improvement than those aged six to eight. In both the milk

group and the milk plus extra lime group, boys showed more improvement than girls. As compared with the boys, girls responded better to the milk plus extra lime. In other words, it did not take so much lime to help the boys as to help the girls. This bears out the general principle that calcium metabolism tends to be stable among males, and unstable among females. An unstable calcium balance is a mark of femininity.

These data, although based upon a relatively small number of cases, are valuable because they confirm suggestions and results presented by other observers. Now, if calcium deficiency and neuroticism are so closely connected, what explains their relationship ? And why are the neurotics in our midst so constantly increasing in number ?

According to Sherman, calcium starvation or insufficiency —a deficiency of food lime—is the commonest form of malnutrition in America among city and town dwellers. There are several reasons for this frequency of calcium deprivation. Most important is the fact that more of calcium than of any other mineral element is required for the work of replacement of calcium losses in the wear and tear or the labour turnover of calcium metabolism.

Calcium, combined with organic matter and phosphorus, forms the solid substance of bone. It is the firm, resistant, yet resilient mass of the skeleton. About 2 per cent of the body weight is lime, of which about 99 per cent is in the bones. Bone calcium, however, is not simply a structural element laid down along lines recently revealed by X-ray crystal studies. It is also the bodymind's great reserve store of calcium. It is the source of lime, upon which the other cells call for calcium when they need it : that is, when there is an insufficient amount of it in the blood ; just as they call upon the liver for sugar, when they need it, mobilizing the glycogen of the liver cells.

Now, the intake of calcium and the absorption of calcium and the assimilation of calcium and the loss of calcium may be made abnormal by many circumstances. Many foods, of the cereal type, are deprived of calcium—decalcified. In modern methods of preparing them for the market, they are shelled, decorticated, which removes most of the lime. Then, lack of sunlight and bad hygiene make impossible adequate assimilation of calcium. There must also be a balanced proportion of calcium and phosphorus in the diet.

There should be about equal amounts, or, at any rate, no greater disproportion than that of one to two. The precise ratio will vary with the endocrine constitution of the individual.

Moreover, few foods naturally contain much of Vitamin D, also known as viosterol. This vitamin is most concerned in assisting calcium and phosphorus assimilation. Also it can in a way act as a substitute for sunlight, or at least for that portion of sunlight called the ultra-violet. Viosterol is formed in the skin when it is exposed to sunlight or ultra-violet light.

The Neurotic Constitution

It is a fact also that cereals, tubers, many fruits, fish, and meat are relatively lacking in calcium. Children brought up on such foods may be normal in all outward appearances. Yet they may be so deficient in lime as to be predisposed to develop a neurotic constitution or personality.

Sherman and Booker carried out a research in which they proved that calcium-poor animals might be produced even when all other conditions and food factors were ideal. They compared animals having the same heredity and brought up under identical environments, but who were supplied with foods differing in their content of calcium. They found that such individuals could appear well nourished and even attain adult growth and maturity with calcium-poor bodies. However, the calcium deficiency would manifest itself under conditions of stress and strain.

At birth the body is calcium-poor and is absolutely dependent upon its food for an adequate supply of lime to use in the making of bone, blood, and nervous system. When there is a call for calcium, such calcium-poor bodies will reveal their weakness.

Among human beings, the neurotics, those who suffer the tortures of neuroses, present evidence of a lack of calcium. Concomitantly they often show weakness of the parathyroid glands which regulate calcium metabolism.

Milk is by no means the only good food for furnishing lime. Cheese, oranges, and even inorganic calcium salts will do just as well, or even better. Besides its uses as building material for bones and teeth, calcium is prerequisite for the normal development and functioning of other tissues. It plays a central role in the coagulation of the blood, it regulates the

heartbeat, and, most interestingly of all, it controls the irritability of the nerves. In the latter function, it acts as the antagonist of sodium. While sodium makes the nerves more irritable and more excitable, calcium influences them to be less excitable and less irritable. A deficiency of calcium, therefore, throws the preponderating pan of the balance down on the sodium side, and nerves become sensitive, readier to react and over-react.

This hypersensitivity of the nerves tends, in children particularly, but also in adults, to make for a brain and a personality which seems to be the prey of its impulses. They lack the ability to cultivate those inhibitions which are a necessity of social civilized life. Such children are called 'spasmophiliacs' and their condition 'spasmophilia'. In adults, the condition is named the 'neurotic constitution'. Its possessors, the much-studied neurotics of civilization, afford much pabulum for those curious about morbid personalities.

To understand the spasmophiliac neurotics, it is necessary to comprehend clearly their relation to calcium metabolism, to viosterol or Vitamin D, and to parathyrin, the internal secretion of the parathyroid gland. They are a most important group for the physician, the parent, the school teacher, and the friends who are brought face to face daily with their pressing problems. For the last ten years, modern knowledge has progressed marvellously to provide powerful curative agencies in the application of calcium and Vitamin D and parathyroid in the medical management of this most difficult group of human beings.

Calcium as a Regulator of all Salt Metabolism

There are a number of mineral salts in food, in the blood, and in the cells, which play a great part in metabolism because of their electrical properties. Sodium, potassium, calcium, magnesium, iron, copper, manganese, all play their significant and essential role in nutrition, combined as salts, namely, the phosphates, carbonates, bicarbonates, chlorides, and sulphates. Each of these functions distinctively, with an importance and a role all its own. Sodium and potassium, calcium and magnesium, iron and copper are in many respects chemical twins. Though relatives chemically, they are by no means interchangeable in the body. Each has a unique function.

In their chemical functions they may be antagonistic, as, for example, sodium and calcium. It is the same with calcium and magnesium. When injected, magnesium tends to produce a general state of relaxation and narcosis. But its effect can be neutralized by an injection of calcium.

Calcium acts as a general stabilizer for all salt reactions in metabolism. Because it has this peculiar property, evolution has produced a gland solely devoted to regulating the amount of calcium in the blood and the way it functions in the tissues. This gland is the parathyroid gland. The four parathyroid glands are so placed and distributed around the thyroid that, even if one or two become injured or diseased, the other two may carry on its fundamental and vital function.

There are no parathyroids in fish, because the sea, as an all-surrounding and all-providing source of salts, made it unnecessary. But with the advent of land life, and the possibility of salt and particularly calcium starvation imminent, it became necessary to evolve a regulator.

No one has ever stated the stabilizing function of calcium in nutrition more succinctly than Meltzer, in 1908, when he wrote: 'Calcium is capable of correcting the disturbances of the inorganic equilibrium in the animal body, whatever the direction of the deviations from the normal may be. Any abnormal effect which sodium, potassium, may produce, whether the abnormality be in the direction of increased irritability, or of decreased irritability, calcium is capable of re-establishing the normal equilibrium.'

Since Meltzer wrote, much work has been done on the calcium problem. Parathyrin, the internal (hormone) secretion of the parathyroid glands, was discovered by Berman in 1923. His research was based upon the idea that the parathyroid glands regulate the amount of calcium in the blood by mobilizing the stored calcium of the bones when needed, just as insulin regulates the amount of sugar in the blood by restituting the ability of the cells to use the stored glucose of glycogen in the liver when needed.

Viosterol, or Vitamin D, assists the absorption of calcium from the intestines, which means from the food into the blood. The parathyroids, by means of parathyrin, effect a surrender of some of the reserve calcium of bone back into the blood. All other things being equal, the amount of calcium in the blood is a matter of the parathyrin-viosterol balance. To

have a normal calcium metabolism, there must be a balance between the food calcium—food Vitamin D—the viosterol content of the skin and the parathyrin content of the blood.

The Balance between Calcium and Phosphorus

Now, children are essentially growing animals—human animals if such a contradiction in terms as 'human' and 'animal' may be indulged. At any rate, they are growing organisms, and it is their chief business to grow bone and muscle and brain. The growth of children cannot exceed a certain limit under ordinary conditions. And these are determined by the inherited capacity of the species functioning through the endocrine glands. For the endocrine glands determine the characteristic physique of any member of a vertebrate species. But to attain the maximum of the endocrine-limited physique, certain optimal conditions of feeding must be maintained. Otherwise, the individual fails to attain the maximum of which he was capable by heredity.

Of these foods necessary for optimum nutrition, the balanced calcium-phosphorus intake is the most important for the growth of the bones. Now, the latter set the pace for the growth of the muscles and soft tissues. Although the growth of the brain and the nervous system is more or less independent of the growth of the bones, there is a relation between them. Through their co-dependence upon a balanced calcium-phosphorus intake, bones and brains are linked. A lack of balance in the calcium-phosphorus intake means not only the badly grown bones and physique of rickets, but also the badly grown brain of spasmophilia.

Both young and older animals may get their calcium supply from such foods high in calcium as milk, cheese, eggs, and certain cereals and vegetables, such as cabbage, carrots, turnips, beets, apples, prunes, and oranges. They may get their supply of phosphorus from lean meat, unmilled wheat and oatmeal, beechnuts, Brazil nuts and almonds, as well as beans. Milk, eggs, and cheese contain large amounts of both calcium and phosphorus. All these foods are broken down more or less completely in the intestinal tract and the calcium and phosphorus absorbed in their simplest form.

How much of them is absorbed depends upon local chemical conditions in the intestinal tract, such as, for instance, the degree of acidity of the intestinal contents. The intestinal

absorption is, therefore, the first limitation to an adequate intake of lime. The second is the ability of the bones to take up calcium and phosphorus as determined by the Vitamin D or viosterol content of the blood, and also by the action of the internal secretions of several of the endocrine glands. Among these, the adrenal glands as well as the sex glands are dominant. And the third limitation is the ability of the bones to *hold* the calcium and phosphorus. This power is regulated by the parathyroid glands.

In practice among adults, all of these have to be considered. Among children suffering from disturbances of the calcium metabolism which reflect themselves in disturbances of the personality and behaviour, the three great factors of the complex—food calcium—Vitamin D—parathyrin—are the triad to be considered. Natural Vitamin D-containing foods may be used. Besides, ultra-violet light or sunlight may be employed directly to increase the Vitamin D effect, as light increases the amount of Vitamin D in the skin and consequently in the blood. Light also increases the amount of Vitamin D in certain foods directly exposed to its action. These, called irradiated foods, are also valuable in treatment.

An increased retention of calcium and phosphorus (the desirable situation in growing children) is effected by such high Vitamin D-containing foods as irradiated cod-liver oil, irradiated milk, or irradiated olive oil. The irradiated olive oil is the most effective of all, which is most remarkable, as ordinary olive oil has no such power at all. Infants receiving these foods are definitely better nourished at the same age than those considered normal. It has been suggested that this means that the accepted standards of growth for infants are too low. It seems likely that conditions which make for better utilization of calcium and phosphorus will result in larger and physically better developed normal children. Even the making of superchildren is in prospect.

At last, it looks as though man, by the aid of science, can now produce adequate repartee to the one who asked, ‘ Which of you, by taking thought, can add one cubit to his stature ? ’ The thoughts of science are long, long thoughts. And now, by means of diet and the hormones of the prepituitary gland, many, many inches may be added and are being added to a human being's length. Will that particular ability profit man

in the long run? Whether to be longer and taller will bring an increment of happiness remains to be seen. At any rate, the restless, interminable, and indefatigable curiosity of man has again made the impossible possible and rendered obsolete one of the ancient dogmas limiting his powers.

Much of what Vitamin D or viosterol does in the organism is a mystery. But as regards the end result of its effect, one fact is certain: It corrects any tendency to an unbalanced calcium-phosphorus ratio with all of its disturbing consequences for the chemistry of the blood and the bones. Shohl and Bennett have shown that a young dog fed a diet containing linseed oil retained less than half of the total calcium in its diet, while it retained more than three quarters of it when cod-liver oil (Vitamin D) was substituted for the linseed oil.

In the presence of a minimum of Vitamin D, increasing the amount of calcium and phosphorus of the food augments the retention of both. Calcium seems to be the determining factor, since in a diet low in calcium and high in phosphorus, there is deficient phosphorus-retention and rickets results.

Optimal development of the bones occurs and rickets is prevented when there is just about twice as much calcium as phosphorus in the diet. This ratio of two of calcium to one of phosphorus reminds one strongly of the ratio of these minerals in the substance calcium phosphate, which is the mineral background of bone. However, in human rickets, evolving in an infant fed on much human or animal milk, the calcium-phosphorus intake is generally enough. The deficiency occurs in the *vitamin-hormone balance.* Therapeutically, such infants respond to cod-liver oil, viosterol, or ultra-violet light, or irradiated foods, rather than to manipulation of the calcium-phosphorus ratio in their food.

The Acid-Alkali Equilibrium

Other elements in the food influence calcium-phosphorus retention considerably. One of these is the amount of acid and the amount of alkali. When meat, eggs, and cereals are burned in the body, they leave an acid residue. A diet containing them tends to raise the acidity of the bodymind. The total acidity has a marked effect upon how much calcium is utilized and how much wasted.

One interesting fact is the observation that increasing the

acidity of the intestinal tract favours the absorption of calcium. That is why orange juice is so remarkably valuable in assisting calcium absorption and assimilation. In the digestive tract, orange juice is acid and favours calcium absorption. After the orange juice is absorbed, its acid salts are burned to form the alkaline carbonates and bicarbonates, and so it actually decreases the acidity of the body. At the same time, it is itself a good source of calcium. Certain foods add acid directly to the body, for example, the oxalic acid of spinach, cranberries, and prunes.

Recently Samuel and Kugelmass published a most interesting comparative study of the influence of acid-forming versus alkali-forming diets on the metabolism in rats. Acid-forming diets shift the acid-alkali balance of the body to the acid side and alkali-forming diets to the alkaline side. They found that an acid-forming diet (and infant feeding régimes are often predominantly acid-forming) which is lacking in Vitamin D provokes a much more severe form of rickets than does the alkali-forming diet. In other words, the acid-forming diets stimulate the loss of calcium and phosphorus. Acid-forming diets were found to *depress the rate of growth and development, metabolism, and activity*. Alkali-forming diets accelerate metabolism, activity, growth, and development. The bones of acid animals were small, brittle, and rickety, their muscles flabby, and their hair shaggy, matty, and patchy ; while the bones of the alkaline animals were large, firm, and healthy, the tone of the muscles was good, and the hair was soft, silky, and grew uniformly.

The differences of activity of the two groups was striking in relation to the blood chemistry. The acid animals tended to be inactive and their lack of activity was associated with a low blood sugar and a tendency to high cholesterol. The alkaline animals tended to be active, and their activity was associated with a high blood sugar and a tendency to low cholesterol. Those on the acid diet had a low alkali reserve in the blood and a consequent tendency to acidosis. The alkaline group had an increased alkali reserve, which was protection against acidosis, but predisposed to the development of an alkalosis.

Keeping the animals in sunlight or darkness exaggerated the effect of the alkali or acid. That is, darkness plus acid produced the maximum shift to acidosis, while sunlight plus

alkali produced the most marked tendency to alkalosis. An acid diet with sunlight produced the greatest increase in the calcium content of the blood, however, while the alkaline diet plus darkness caused the greatest lowering of the blood calcium. Nevertheless, *it is on an alkaline diet in the summer when exposed to sunlight that animals make their greatest weight gains.*

The Effect of Sugars and Cereals on Calcium Retention

Not all foods are equivalent in the availability of their calcium and phosphorus for the needs of the body. So that a mere table of calcium contents does not tell the whole story regarding the lime values of foods. Two sugars, like sucrose or cane sugar and lactose or milk sugar, may seem equivalent in a number of respects. But milk sugar facilitates calcium retention, while cane sugar has an opposite effect. Lactose probably assists absorption of calcium from the intestinal tract because it is there fermented into lactic acid, increased acidity dissolving more of the digested calcium. Cane sugar, on the contrary, tends to dissolve in the stomach and depress the acidity of the stomach and intestinal contents. As for milk, even the manner of physical treatment of it in preparing it for consumption makes a difference. Evaporated milk or quickly boiled milk has its calcium in a more assimilable form than that of the more slowly heated pasteurized.

Now, while Vitamin D may be described as a calcifying (calcium assimilation assisting) substance, other substances have been found in foods which are anticalcifying or decalcifying. They tend to rob the body of calcium. Most commonly, these occur in cereals, especially in the celebrated Scotch cereal, oatmeal. Arranged in a series of relative decalcifying power—as measured by their ability to make rickets worse in the absence of Vitamin D—the cereals may be placed thus: oatmeal, corn, barley, rice, whole-wheat flour. White flour and polished rice—cereals deprived of their calcium—were the least decalcifying.

Cereals containing the most calcium and phosphorus (such as brown rice and whole wheat) in properly balanced proportion and with a slight acidity were discovered to be the most anticalcifying. Such an undesirable effect from foods desirable in so many other respects is startling.

Mellanby, of London, and Holst, of Oslo, say the reason for

this undesirable effect is the presence in these cereals of anti-calcifying antivitamin substances, which they call ' toxamins '. These interfere with the proper assimilation of calcium. Their action, therefore, is definitely opposed to that of Vitamin D. The addition of Vitamin D to a cereal neutralizes its pernicious effect upon calcification. If oatmeal, for example, is irradiated with ultra-violet light, increasing its viosterol content, its anticalcifying effect is abolished. When the cereals are supplemented by foods like liver, lettuce, or eggs, the anti-calcifying effect is nullified.

Cereals are not the only offenders in harbouring toxamins. Vegetables, such as spinach, may also contain anticalcifying substances. The practical conclusion to be drawn from these discoveries concerning the anticalcifying effect of certain cereals and vegetables is that the Vitamin D content of the diet must be proportionately higher when the diet contains these cereals and vegetables.

One of the most interesting findings concerning the availability of the calcium of pasteurized as contrasted with boiled milk has been reported by Daniels. Of the many babies studied by her, the retention of calcium was three times as great with *milk quickly boiled* as with the *slowly heated pasteurized*. Evaporated milk, milk concentrated by the evaporation of about 60 per cent of the water in a partial vacuum, has its calcium in an easily assimilable form. That is why evaporated milk has proved so valuable in the feeding of certain infants.

But it is quite the antithesis with its rival, sweetened condensed milk. One way to measure the action of different milks is to determine their effect upon the strength of growing bones in resisting fracture. According to a study, made in Vermont in 1916, of the breaking-point of bones in animals on different milk diets, raw milk was the most effective in making the strongest bones. The superiority of evaporated milk was obvious, as compared with sweetened condensed milk or pasteurized milk.

Dried milk has about the same disadvantages as pasteurized in respect to calcium retention. When pasteurized or dried milk is used in infant feeding, special attention should be paid to the matter of Vitamin D supplement of the diet. If it cannot be added to the food, it should be provided by exposure to sunlight or ultra-violet light.

Ergosterol, Begetter of Vitamin D

It was during the experimental study in the laboratory of a bone disease, rickets, that the information detailed in the preceding paragraphs was obtained. When it was found that animal rickets could be produced experimentally by a diet low in phosphate, it was easy enough to test the healing effect upon it of the two agents used successfully in the treatment of human rickets—cod-liver oil and sunlight or ultra-violet light. Cod-liver oil had been used successfully in human rickets for generations. It was known to favour a positive calcium balance in individuals to whom it was administered.

Ultra-violet light was introduced by the German Huldschinsky in the years immediately following the War of 1914–18. He worked with children deformed by rickets at the Oscar-Helene Home for Crippled Children. A number of the laboratory workers found that both cod-liver oil and ultra-violet light could cure experimental animal rickets. The curative substance in the cod-liver oil was named Vitamin D, to distinguish it from Vitamin A, which is also present in cod-liver oil. When it was found that the two agents—Vitamin D and ultra-violet light—have the same action in curing rickets, it was realized that there must be some definite relation between them.

Almost simultaneously two men became possessed of an idea that was the clue to that relation—to observe whether ultra-violet light acting upon food lacking the power to prevent or cure rickets could endow such food with that power. Hess turned ultra-violet light upon linseed oil and cotton-seed oil, and found that such irradiated oils could cure rickets, as well as cod-liver oil, although the non-irradiated oils could not.

Steenbock turned ultra-violet light on the entire experimental ration, and proved that such irradiation caused the appearance of Vitamin D in it, with its characteristic curative and preventive power against rickets. So it was shown that Vitamin D was generated in various foods in oils and fats, in cereals and vegetables and green leaves, by the chemical activity of ultra-violet light. Even fruits like oranges and foods and milk have had their content of Vitamin D much increased by irradiation.

The secret of the magical witchery of ultra-violet light in

rickets having been pierced, it remained to be discovered just what the mechanism of its action is when it confers its beneficent effect upon foods. At once the question arose: Is the effect of light due to its effect upon some single substance in the irradiated foods—a substance which would therefore be entitled to be called pro-Vitamin D—or to its effect upon a whole series of substances, perhaps entirely unrelated to one another? Its presence in cod-liver oil suggested that it might be of a fatty or oily nature. A remarkable series of intensive researches resulted, prosecuted with ruthless logic by the German biochemist Windaus, for which he was awarded the Nobel Prize.

First he discovered that the action of the ultra-violet light was upon a group of substances found in living matter which are solid alcohols, known as sterols. They make up the major portion of the cod-liver which cannot be turned into soap when boiled with alkali. The best known of these sterols is cholesterol, which is present in the cells of all animals and plants. It occurs in quite large amounts in gall stones (where it was first found), the bile, blood, brain, and skin. It was shown that ordinarily purified cholesterol, when irradiated with ultra-violet light, becomes a substance with a remarkable degree of Vitamin D potency.

But further purification of the cholesterol showed that the purest cholesterol was not so affected by ultra-violet light. Some impurity in the cholesterol was responsible for the effect. This substance has turned out to be another sterol. It is called 'ergosterol', because it was first found in quantity in ergot. It is also extractable in fair amounts from mushrooms, fungi of various sorts, and yeasts. It is present in rather small concentration in all plant and animal cells.

It is now universally accepted that it is ergosterol which is the substance transformed by light into Vitamin D. Such irradiated ergosterol is now officially named 'viosterol'. Slight doses of it exhibit a most amazing potency in curing the rickets of rats, puppies, and children. Unit for unit, viosterol is about a million times as active as cod-liver oil in promoting the retention of calcium and hence of phosphorus. A certain amount of viosterol is normally present in circulating blood.

Substances which have the capacity of absorbing light or certain wave-lengths of light can be analysed quantitatively

by means of the spectroscope. An absorption spectrum is obtained, which is the ordinary rainbow spectrum of light. Ultra-violet light is black light ; that is, it has no colour. The spectrum of ultra-violet light may be obtained as a black band punctuated by vertical lines at the points at which the light is absorbed.

In the ultra-violet spectroscope there is a source of ultra-violet light and a quartz prism through which the light is transmitted, throwing its spectrum upon a photographic film. If the substance in the quartz container does not absorb light—pure alcohol, for instance—the film simply shows the characteristic spectrum of the light. But if it is a substance which does absorb light, such as cholesterol or ergosterol, the spectrum shows the bands characteristic of the substance. These bands vary in intensity with the amount of light-absorbing substances present. By comparison with a standard, an exact determination of even traces of the active substances may be possible.

By means of such spectroscopic analysis, ergosterol has been demonstrated in all kinds of foods. And, in fact, it seems to be the most widely distributed of all the sterols. That is what one would expect, considering its importance as a source of Vitamin D. It is interesting that the ultra-violet light waves which ergosterol absorbs when it becomes changed into viosterol are of about the same lengths as those found capable of curing rickets, when the skin is irradiated with them.

Considering the relatively wide distribution of ergosterol, one might expect that Vitamin D would also be widely distributed and found in so many foods that there would be no danger of any deficiency of it in an ordinary mixed, everyday diet. Actually Vitamin D occurs in relatively few foods in quantity sufficient to protect against the dangers of lack of it. That is why exposure to sunlight and ultra-violet light is a necessity even for those partaking of adequate amounts of ergosterol-containing foods.

For those people who have attempted to belittle the importance of the vitamins on the ground that they are vague, indefinite, and intangible, and also invisible, it will be unpleasant news that at least one of them, Vitamin D, has been obtained in crystalline form. It has been accomplished by Windaus, who showed that viosterol, the artificial Vitamin D, could be made by treating ergosterol with ultra-violet light.

There can be absolutely no doubt of the effectiveness of this crystalline vitamin, because the most exact measurements have been used in testing its potency.

Even more recently, Professor Windaus has obtained two different crystalline substances of Vitamin D, as a result of the irradiation of ergosterol. He calls them Vitamin D_1 and Vitamin D_2. The Windaus Vitamin D_1 has about the same activity against rickets as Vitamin D_2, but it differs as regards other properties. At the same time a group of workers at the National Institute for Medical Research have reported crystallization of a substance even more effective against rickets and therefore containing the purest Vitamin D known. They call this substance ' calciferol '. They have demonstrated also that their calciferol is a product of the treatment of ergosterol, the parent substance of all these Vitamins D, with ultra-violet light. Calciferol has the same elements in the same relative proportion as ergosterol. It is, therefore, an isomer of ergosterol, nothing added to or subtracted from it, but the atoms rearranged in it to make an entirely differently acting compound, so far as the physiological effects on the organism are concerned. All the Vitamins D seem to be isomers of ergosterol.

Fish, the Synthetic Chemists of Vitamin D

The discovery that cod-liver oil contains large quantities of Vitamin D has become an enormous boon for the cod-liver-oil industry ; just as the discovery of the value of liver and liver products in pernicious anaemia has been followed by greatly increased profits for those who deal in them. In the years from 1922 to 1927, during which intensive and interesting researches upon rickets, Vitamin D, and calcium metabolism were being published in an unending stream, and the medical profession was made cod-liver oil conscious, the importation of the oil into the U.S.A., for instance, was more than doubled.

Cod-liver oils themselves vary much in their Vitamin D potency. The cod is not dependent upon a supply of the ultra-violet light to construct the Vitamin D present in its liver and extractable as its liver oil. The cod are generally caught in the spring or summer when the livers are largest, weighing in Newfoundland about one-fourteenth of the total weight of the fish. At this time about half of the liver consists of the oil. Yet, under artificial conditions in the

winter, when the fish were fed little and their livers were so small that ether had to be used to extract the oil, a very dark oil, two hundred times as strong as the summer oil, is obtained. It seems that, though the fat of the liver is consumed during the winter starvation, the vitamin oil is saved and becomes concentrated.

The liver of the cod, therefore, is a synthetic chemist, manufacturing the Vitamin D out of raw materials in its food without the assistance of light. Other fish livers have the same capacities—for example: burbot livers, shark liver, haddock liver, and globe-fish liver. The globe-fish elaborates an oil fifteen times as powerful as cod-liver oil. Burbot is a fish found in the Great Lakes and tributary streams and has been described as the 'nearest fresh-water relative of the cod'. Its liver oil has been assayed as eight times as strong as cod-liver oil.

But not only the liver, but also the body oils, of various fish contain the vitamin in appreciable quantity—probably due to its passage from the liver to the muscles. Thus Newfoundland herring and California sardines have been shown to be as active as cod-liver oil itself. Salmon has about one-fifth of the potency of cod-liver oil. Fish, especially fatty fish, therefore, may be considered the most generally accessible and valuable source of Vitamin D.

Fish-eating peoples, such as the Japanese and the Icelanders, do not have rickets. A certain amount of ultra-violet light is necessary, though, for the inhabitants of the Faroes, a place usually covered with mist which fails to transmit the ultra-violet rays of the sun, have a certain amount of rickets, even though they also live on a fish diet.

Vitamin D in Other Foods

Another form of fat good for its Vitamin D content is egg yolk. But the eggs have to come from hens that are on an adequate diet and exposed to ultra-violet light or sunlight. Hens, in other words, cannot synthesize the Vitamin D as fish can in the absence of the right light wave-lengths.

Many attempts have been made to increase the Vitamin D content of cow's milk in various ways—by irradiating the cow, for example—but with no important effect. Recently Steenbock reported that, by adding irradiated yeasts to the diet of the milch cow, the concentration of viosterol in its milk was

increased by about eight times. Milk is now being made in this way for public sale. It looks as if ultimately a milk will be available containing all the vitamins and minerals ordinary milk lacks. An interesting fact is the observation that, unlike the cow, the goat can be made to give a high Vitamin D milk by simple irradiation of its body with ultra-violet light. Human breast milk contains little or no Vitamin D.

Another curious fact is the observation that cereals and vegetables, grown in the sun and exposed as they are to ultra-violet light all summer, have little or no Vitamin D, though they do possess significant amounts of ergosterol, as proved by the fact that when they are artificially treated with ultra-violet light they are made Vitamin D active. There is thus demonstrated a fundamental difference between the growing plant and the harvested. Clover hay, for example, contains no Vitamin D, nor has it when dried in the dark. But it develops a considerable concentration of it when dried in the sun.

The Uses of Natural Ultra-Violet Light (*Sun Baths*)

As is well known, ultra-violet light is black light or invisible light. Ordinary white light consists of wave-lengths in the range of the coloured spectrum. Beyond the violet rays there are shorter wave-lengths than the adjacent coloured light-waves, which do not affect the retina with either a sense of colour or light. These ultra-violet rays have also been called the chemical or actinic rays because they were first recognized by their chemical action, for they speed up certain chemical reactions, such as those which occur on a photographic plate. These are sometimes designated as the 'photochemical' effects. It is for their photochemical effect upon ergosterol that they are useful in food and health. They accelerate the chemical reaction which changes ergosterol into Vitamin D.

Now, though the name ultra-violet applies to the whole range of waves beyond the violet, as the name implies, it is only a short sector, quite near the visible violet, that is responsible for the photochemical effect. It is for that sector upon which we are dependent for the normal growth of our bones and that maintenance of vitality which is dependent upon a normal calcium and phosphorus balance. This sector of the ultra-violet spectrum, which might be called the Vita-

min D-ultra-violet sector, represents a specific form of light energy. It is abundant only during certain months of the year. Relatively it is quite fragile in its susceptibility to destruction or interference by various agencies of an environment.

According to its source, moreover, ultra-violet light differs not only in wave-lengths, but also in its strength and intensity. These can be measured by its effect upon the skin. The pigmentation of the skin which follows exposure to a sufficiently intense source of ultra-violet light is comparable to the sunburn following exposure to strong sunlight. The amount of ultra-violet light producing a reddening of the skin comparable to sunburn is called the 'erythema dose', and the reaction is called the 'erythema reaction'. Such an erythema reaction to ultra-violet light may be used to standardize the dose of its intensity. And of course sunlight sunburn is due to the large quantity of ultra-violet rays in ordinary sunlight.

Instead of employing the sunburn or erythema reactions directly to measure ultra-violet rays, they may be standardized by their photochemical effect upon chemicals in test-tubes. Two such convenient tests have been elaborated. One is dependent upon the fact that ultra-violet rays will decompose oxalic acid—the oxalic acid test. The other depends upon the fact that ultra-violet rays will darken a zinc sulphide paste. The erythema reaction, then, can be gauged in terms of photochemical reactions. Thus the activity of an ultra-violet lamp may be calibrated without resort to the human skin.

Sunlight—which in relation to calcium metabolism means natural ultra-violet light—differs markedly with the latitude, longitude, and altitude of a given geographical area. Besides, local conditions affect the transmission and reflection of light, such as the state of the atmosphere and the time of day. So a good supply of ultra-violet light rays may be rendered worthless for the human beings dependent upon them. There are more of them on mountain-tops than at sea level, although it is also known that bodies of water will reflect them to an extent sufficient to produce a marked sunburn and tanning.

The Curse of Coal

Smoke and fog, haze and cloudiness, will block and destroy ultra-violet rays. By a characteristic irony of the fates one

and the same phenomenon—the exploitation of coal—had effects both beneficient and deleterious upon the English people during the nineteenth century. Coal-mining ushered in the Industrial Revolution and made England the centre of trade with its factories. But these factories, belching forth their smoke and obscuring the sky with their pall of dust and coal gases, tended to make a rickety nation of the English. The percentage of physical defects and degeneracy revealed by the war ordeals of 1914–18 among them was greater than in any other belligerent nation.

English people have always had a tendency to rickets (probably for endocrine and vitaminic reasons). Rickets was first adequately described by an English physician and has since been known on the Continent as the ' English Disease '. There can be no doubt that the blanketing of the sky by coal products, which filtered out the ultra-violet rays, was responsible for the prevalence of a great many of the physical and mental defects now found in so large a proportion of the population.

In Chicago, the investigations of Bundesen, Lemon, and their collaborators have demonstrated that the combination of winter and coal smoke almost completely excludes the ultra-violet rays. The irascibility of the Chicago gangster may be a function of the ultra-violet content of the atmosphere. In Baltimore, it was proved that the intensity of the rays varied inversely with the degree to which soft coal was burned and coal soot produced. Skyshine, the reflected sunshine of the northern horizon on a clear bright day, contains enough ultra-violet energy in the summer. But in general, whatever overcasts the sun at midday means a reduction or nullification of the Vitamin D-forming, calcium-retention-promoting ultra-violet rays.

The time of the day makes a difference in the ultra-violet ray content of the atmosphere. At noon the sun is nearest to us. At about noon, then, astonishing differences in the intensity and wave-lengths of the ultra-violet have been found as compared with early morning or late afternoon. The time, then, to take a sun bath is between eleven and two o'clock. And in summer, when the sun is nearer the earth, there is naturally more of the ultra-violet energy that penetrates the atmospheric envelope of the earth.

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The Value of Nudity

The conditions under which man lives, housing and clothing and cleanliness, have a profound effect also upon his metabolism. They tend to interfere with proper exposure to sunlight. Dirt stops the ultra-violet rays. Ordinary window glass, which has come into use only in the last few hundred years, and is therefore listed as one of the achievements of civilized progress, has turned out to be another of the curses in disguise involved in the application of scientific knowledge. Before the invention and general adoption of window glass, windows were simple holes in walls through which air and light could enter without hindrance. Now it has been shown that the substance of glass absorbs the ultra-violet rays. It follows that indoor filtered sunlight is useless, even when procured from the most southern of southern exposures.

However, science is redeeming itself—as it will redeem itself in all cases where its discoveries prove harmful to mankind—by manufacturing varieties of glass which are permeable to the beneficent rays. In Boston, Mass., for example, Wyman has reported that babies with rickets, kept undressed all day long in the winter in cribs facing windows made of ultra-violet-transmitting quartz glass, remained free of rickets on diets provoking rickets in infants not so managed.

It must be remembered that, as with ultra-violet lamps, ultra-violet glass becomes weaker with time. That is, the permeability to the rays gradually decreases. But after a certain point, this process ceases, and the glass may still be good.

As regards clothing, the effect of weave, colour, kind and thickness of fibre, as well as the ash content of the fibre, have all been studied. There can be no doubt that the everyday costumes of our climate, especially during the winter, practically rob the body of the beneficent effects of the ultra-violet rays of the sun. Coblentz and his collaborators of the United States Bureau of Standards have carried out some ingenious experiments concerning these effects. They measured the amount of light passing through a cloth when coloured white and the same kind of cloth when dyed black. A well-knit piece of goods like cotton broadcloth will transmit about 10 to 20 per cent of light, for instance, while such loosely woven materials as voile or georgette will permit as much as 55 to 65 per cent to go through them.

Any coloration of a fabric, even a light yellow, will interfere with the passage of the light. There are also differences due to the nature of the fabrics themselves—cotton, linen, and artificial silk transmit more of the ultra-violet than do silk or wool. The porosity of the material, which depends upon the percentage of ash contained in the fibre, explains the difference between natural and artificial silk, the latter having much less ash in its substance. Obviously, then, the thinnest and most loosely woven garments of cotton, linen, or artificial silk are the desirable ones, next to nudity, for those suffering from defects of calcium metabolism, and for protection or prevention of the diseases of personality connected with it.

Ultra-Violet Lamps

Ultra-violet lamps are of two kinds—the quartz lamp or mercury vapour lamp which produces mainly ultra-violet rays, and the carbon lamp, which generates the whole spectrum of rays including the red-yellow as well as the ultra-violet. The ultra-violet rays are absorbed by the skin and do not penetrate farther than the pigment layer of the skin. So-called white human skin is a better transmitter of ultra-violet rays than the negro skin because of this fact. The red-yellow rays penetrate farther, as shown in the rosy pearl colour of the ear when sunlight shines through it, or the pinkish glare of a finger held in front of a carbon lamp.

In using the lamps (mercury or carbon) for affecting the calcium metabolism in human beings, the eyes are protected with darkened glasses or a cloth. At the first exposure, the nude skin is exposed, front and back, each for a half-minute only. The duration of the treatment is increased gradually, the limit being set at ten to twenty minutes.

In several nursery schools, where the children have been allowed to play naked while exposed to the lamps, improvement in the zest of living and vigour, as well as in resistance to disease, have been reported. This undoubtedly presages the means of solution of the ultra-violet light problem for children during the winter.

Upon the mentality and nervous systems of adults, the effect of such irradiation is also striking. After an irradiation of the entire nude skin, there is a feeling of stimulation and invigoration, and the irritability or depression of fatigue is abolished. Hausman, for instance, has described his reaction

of exhilaration and *joie de vivre* as much like the after-effects of a mountain trip.

In a group of children afflicted with poor appetite, lack of vitality, and absence of animal energy, irradiation with the ultra-violet rays for three-quarters of an hour, five days a week, for a month, resulted in what amounted to a change of character. Skin and muscles were transformed from pasty and flabby to firm and well-toned tissues. At the same time, appetites were regained, sleep became natural, and a cheerful playfulness and incorrigible optimism became prominent.

An overdose of irradiation, or a small dose in a susceptible individual of a certain type, may produce insomnia, apprehensiveness, and a peculiar feeling of unrest before any skin reaction appears. A history of susceptibility to sunburn, or sun reactions, may often be obtained as a warning of the dangers involved in the use of the ultra-violet rays in such individuals. The use of ultra-violet irradiation, like the use of Vitamin D, may easily be overdone, and should not be carried out except under the supervision and continued observation of a physician.

Calcium Character Disturbances

All these observations about the relation of ultra-violet light and Vitamin D to calcium metabolism have an important bearing upon the recognition and control of certain nervous disturbances of character and behaviour. These occur frequently among children as well as among adults. Such people are now popularly described as ' neurotics '. Chemically they may be designated as the insufficiently calcifying people of our civilization. They are the *uncalcified-maladjusted.*

Their maladjustments are physiologically connected with the conditions of urban civilized life because these conditions interfere with the proper supply of sunlight and ultra-violet light for their skins. Urban life forces them to live upon adulterated food, with a consequent insufficient intake of calcium and Vitamin D in their denatured, unbalanced diets. Psychologically, civilization is a strain because of their sensitive nervous system and psyche.

These effects are most marked in those who are born with a tendency to react to slight deficiencies of calcium, because of congenitally weak parathyroid glands. There may also be an acquired inefficiency of the parathyroid glands due to the

damage of the diseases of childhood, such as scarlet fever or whooping cough, particularly the latter. The toxins of these diseases may definitely injure other glands of internal secretion. Also, a disturbance of the calcium metabolism predisposes to the development of the infectious diseases.

Among children, the outstanding character disturbances occur in the domain of social adaptability. At home, in school, with their playmates, or in whatever other environment they may be thrown, they have a difficult time and make things extremely difficult for everyone else by their lack of adaptability and refusal to make the usual social compromises. By their parents, teachers, or guardians they are called incorrigible, quarrelsome, unamenable to discipline. When aroused, contradicted, thwarted, or irritated to the slightest degree, they become violent and assaultive. They are described as ' little furies ', becoming uncontrollably angry at the least provocation. On the slightest pretext, a look misunderstood, words wrongly interpreted, or a gesture misconstrued will arouse marked antagonism, immediately translated into action. A slight reprimand or a hint of disciplining attitude on the part of parents or relatives at home at table may provoke the throwing of a plate or knife or any other object nearest at hand. In school, shouts, curses, blows, will be fired suddenly at any supposed aggressor, be it fellow-pupil or teacher. Negativism, refusal to agree with anything said or suggested, is characteristic. This form of throwing mania is the sort of behaviour in these children that sometimes becomes a reason for confining them in institutions.

In general, the character disturbance may be described as one of the individual being literally possessed by a hair-trigger irritability which makes impossible the development of the necessary inhibitions and controls of social intercourse. ' Tantrums ' is the name often used to designate their attacks. Other bad habits that may manifest themselves are blinking, nose-scratching, head-nodding, face-twitching, bed-wetting, and others of various sorts. None of these need be present and there may be other explanations for them. But a disturbance of calcium metabolism—calcium assimilation and calcium utilization—should always be suspected when any of them is associated with the character manifestations sketched.

Now, when these children come to be examined, they present the characteristic and definite physical signs, blood

chemistry, and X-ray findings of spasmophilia, including other qualities of what I have described as the parathyroid-centred personality.

Physical examination shows a marked irritability of the muscles and nerves. Irritability of the muscles, known as 'myotatic irritability', may be elicited by testing the deltoid or pectoral muscles at the shoulder. Percussion of these muscles lightly produces a quick contraction of the muscle, forming a groove at the point of percussion, or repeated quiverings of muscle fibre bundles. Percussion of nerves at the points of their greatest proximity to the skin will result in an excessive contraction of the muscles controlled by the nerves.

Thus, tapping on the cheek or the front of the ear will produce a slight twitching of the mouth or eye muscles—the Chvostek facial reflex. Tapping the radial nerve just below the bend of the elbow will result in a sudden extension of the thumb. Percussion of the tongue may cause a dimple to appear at the point tapped. A momentary swelling of the muscles, myoidema, may follow the percussion tests, when the condition of calcium lack is extreme.

Now, in addition to these qualitative tests, demonstrating the hair-trigger excessive irritability of the muscles and nerves in these children, the degree of excitability of the muscles and nerves may be accurately measured by means of electrical instruments. The amount of electricity necessary to provoke a response to stimulation of the ulnar nerve at the elbow, or the peroneal nerve at the knee, may be easily and quickly determined, and stated in terms of millimetres or microfarads. This is the best and most accurate means of measuring parathyroid function at our disposal. The parathyroid-deficient spasmophiliacs may show from 100 to 1,000 per cent increase in the electrical irritability of their muscles and nerves. That is, it will take from one-half to one-tenth of the normally adequate stimulus to provoke a reaction.

When the calcium content of the blood is reduced by various measures—most definitely by elimination of calcium from the diet or by weakening or destruction of the parathyroid glands—it takes less of a stimulus to provoke a reaction in muscle or nerve. And in the case of a stimulus accurately measurable, like electricity, there is a direct parallelism between the two.

When examined, these impulsive children show a lowered

calcium content of the blood. If not, they will show an increased phosphate, or a disturbed ratio of the two, even if the calcium is relatively within the normal range. X-rays of the bones show a poor calcification, the calcium shadows of the whole structure of the bones being much less well-defined than they should be. All of which tends to demonstrate that there is an underlying defect in the distribution and utilization of calcium.

Another interesting pertinent fact is the one reported by Quest in his studies of the brains of spasmophiliacs. He reported that there is less than the normal amount of calcium in their thalamus, one of the great ganglia of the brain. Now, all the evidence concurs to establish the thalamus as the most important emotional centre of the nervous system. The lack of calcium in the thalamus may be the true basis for many tragedies of families and individuals.

Because they are so tense, sensitive, and keen, these children may be strikingly witty, intelligent, and so-called 'precocious'. Their faces make them look older than their natural ages, because there is a certain troubled expression in many of them. This, the Uffenheimer facies, is due to a greater than normal degree of contraction of the facial muscles which is characteristic. The melancholic, worried look also expresses the irritability of their internal viscera. An unsympathetic, uncomprehending observer wonders why they begin so young to carry the world on their shoulders. Though they may be intelligent, they find it hard to concentrate because they are so distractable. And so they may be rated much lower in school than their intelligence as measured by the I.Q. and general reactions should warrant.

Yet they may get along well in school in those subjects demanding only the ability to visualize. For many of them have that curious faculty to remember photographically what they see, called the 'eidetic capacity'. But even this may produce character disturbances—for they may be haunted by what they have seen. The eidetic calcium imbalanced characters of history and folklore have been the witnesses of ghost stories and legends and the originators of religions.

The Early History of Spasmophiliac Neurotics

When one goes into the early history of these children, characteristic occurrences, accidents, and symptoms will be

elicited. A history of attacks of croup is frequent, or a history of attacks of spasm of the larynx. During crying or laughing, there may have been a slight whoop, or a crowing sound with inspiration. Or there may even be a history of severe crises of respiratory difficulty, in which the face becomes pale and the lips purple, the head is thrown back, breathing stops, the eyes protrude, and fainting with loss of consciousness follows. A spasm of the larynx may have in its wake the typical convulsions of spasmophilia, which, however, may occur independently of spasms of the larynx. These symptoms are commonest in the first two years of life.

General convulsions may have been recurrent, happening at any time, from shortly after birth, from the third month to the age of seven years, or up to puberty, concomitantly with teething, indigestion, constipation, infection, or any other sort of illness, which whips up the metabolism and increases the loss of calcium. Between the ages of four and seven, 'absences' of consciousness, without loss of consciousness, may replace the convulsions. The latter may simulate an epileptic attack in every respect, including biting of the tongue and a tendency to fall into a deep sleep afterwards. They are the 'psychic equivalent' of epilepsy, during which the individual may commit acts, even crimes, of which he is totally unaware afterwards.

Or there may be isolated spasms of the muscles of the hands or the feet, without loss of consciousness, with a history of true tetany. They are like the convulsions due to removal or injury of the parathyroid glands, producing convulsive spasms in different parts of the bodymind. Such a spasm may wedge the thumb in between the fingers, or all the fingers may spread out stiffly. Spasms may have occurred in the smooth, involuntary muscles of the bronchial tubes, which presents itself clinically as attacks of asthma (spasmophiliac asthma). Or there may have been spasms of the stomach and intestines (gastro-intestinal tetany), with its concomitants of spasm of the pylorus and intolerance for ordinary cow's milk.

In children of the type, there may be a history of a great deal of trouble in finding a formula that would not be followed by vomiting or indigestion. Atropine may have been used successfully in combating these local spasms. But it does not affect permanently the underlying condition of insufficient

calcification, which reveals itself in disturbances of character development in after-years.

Physical examination may show some of the residues of an ancient rickets, or what may better be designated a 'latent' rickets. For the rickets may flare at any time during the growth period, which means at any time until the completion of puberty. There may be the large squat head and the bulging Olympic forehead.

There may be signs of delayed and defective dentition. The dental age may not be the equivalent of the chronological age; that is, all the teeth that should be erupted for the age are not present. The enamel of the teeth may be ridged, irregular, chalky, or pitted. Caries, with interferences by the dentist having left their mark, may be prominent. Knock knees, bow legs, and flat feet may be present. The ends of the long bones and the ribs may still be swollen.

A certain proportion of spasmophiliacs are the product of heredity. They have been born with relatively weak or inefficient parathyroid glands. A history of spasmophiliac manifestations on one or both sides of the family for several generations back is often obtainable. Most of the others are the result of the strain incurred by the parathyroid glands during the course of rickets. As these glands react in response to the disturbance of calcium metabolism, they enlarge and overfunction for a time, just as the thyroid will enlarge and overfunction for a time, in reaction to an iodine deficiency. But after a while, the strain of overwork, or an absence of an adequate period of recuperation, tells, and the defective secretion of fatigue follows. The spasmophiliac phenomena in the domain of the mind, the emotions, and character then follow, as well as the manifestations of disturbed bodily functions. The prevention of rickets in infancy will mean the prevention of acquired spasmophilia in many individuals.

It is easy to realize the importance of recognizing these cases of character disturbances in calcium deficiency. In view of what has been said concerning the remarkable effects of a diet high in calcium and Vitamin D on calcium assimilation and retention, the treatment is obvious. When combined with the use of ultra-violet light and injections of parathyrin, the metabolism of calcium becomes remarkably stabilized and there is a disappearance of the disagreeable and anti-

social character. The following case illustrates a typical result in a child who was about to be committed to an institution when brought for examination:

This was a little girl, five years of age. She was the third of a family of four children, all girls. Her sisters were quite well, gave no trouble to their mother or to their friends or at school. But the patient could not get along with anyone —her mother, her sisters, her playmates, or her kindergarten teacher. Her trouble was a complete lack of self-control under excitement or provocation of any sort. When crossed by a hasty word or a misconstrued look at the table, she would throw dishes, knives, or anything else that was at hand. She quarrelled and fought with every child she met, almost with every stranger she met. To a lady visitor who attempted to pet her, she said, 'Get your hand off my coat; put it on your own coat.' If there was any property around, such as a toy or a coin, she would walk off with it without any hesitation whatsoever.

Her father and mother were both well, the father being of a somewhat neurotic type. The mother related that she had had a profuse haemorrhage shortly before the child was born. At birth the girl was definitely overweight. Early in her development, she exhibited a tendency to rock her head madly when annoyed.

Upon examination she showed the signs of deficiency of the parathyroid glands. Because of this deficiency, there was an insufficiency of lime in her blood and nerves and brain. The nerve current moved too quickly for the development of normal inhibitions. This accounted for her irritability, her quarrelsomeness, her lack of consideration for others, and her explosive outbursts. Under the above outlined treatment she became a changed being. She became social, and 'sensible', as her mother put it. After several months, she was getting along perfectly with her sisters, her mother, and her school friends. Her work at school improved astonishingly.

Untreated spasmophiliacs and badly treated spasmophiliacs form a group among whom the introverted neurotic of adult life germinates. Then there are the latent spasmophiliacs (those never subjected to sufficient stress and strain to make manifest their condition). Upon careful examination these introverted neurotics show evidences of unbalanced, unstable calcium metabolism, and signs of deficient or inefficient func-

tioning of the endocrine glands concerned in calcium metabolism, particularly of the parathyroid glands. Often the history of calcium deficiency leads back to childhood.

The prevention and adequate treatment of spasmophilia, latent or manifest during childhood, would mean the prevention of many neuroses and breakdowns in adult life. The response to treatment of these calcium-poor introverted neurotics is a further indication of the value of this viewpoint in the restoration of neurotics to adequacy. This by no means asserts that all neurotics are calcium-determined. But there can be no doubt that many have an unstable calcium metabolism as the background of their neurotic constitution. Such calcium-centred neurotics will be much assisted by detailed attention to the character of the diet, the use of clothing, sunlight and ultra-violet light, and—most important—the application of parathyrin, as the following case history shows:

This was a man who came because of a nervous breakdown. He had lost his ability to concentrate and thus became unable to keep his mind on anything, so that he had to give up his work as an architect. He had developed a tendency to insomnia, and even reading all night failed to tire his brain to the point of sleep. By day, he could not sit still, being continually fidgety and restless. Indigestion and tremulousness completed the story of his complaints.

As a child he had had laryngitis frequently, was much depressed most of the time, and had thought of suicide. His ability to visualize photographically was perfect, and he received 100 per cent in geography and geometry because of this. He could do complicated mathematical problems in the dark. After puberty this eidetic ability was lost.

The physical and laboratory examinations demonstrated a number of the earmarks of parathyroid insufficiency. The sensitivity of his nerves was ten times that of the normal. He was put on a high calcium, low phosphorus diet and simultaneously given hypodermic injections of parathyrin. In about a month he proclaimed himself a changed man. Treatment was continued for several months, at the end of which time he returned to work. The sensitivity of his nervous system was approximately normal. He has continued doing work which requires a high degree of concen-

tration, he sleeps well, and has good nervous control of his general daily behaviour.

All these considerations show that every human being suffering from a neurosis, or 'nerves', 'nervousness', or a neurotic constitution in any way is at least entitled to an examination of the state of the parathyroid glands and the calcium metabolism. They also show why no mental treatment of these neurotics, even psycho-analysis, should be carried out without taking account of the food metabolism and the condition of the endocrine glands. They also provide the best kind of positive, concrete evidence for the practical value of the bodymind attitude for the physician in dealing with patients.

CHAPTER VIII

SUGAR AND THE ENERGETIC PERSONALITY

OF all new human enterprises—and in America this means, in the majority of cases, of all new 'business' ventures—it is said about 90 per cent are failures. It is still an open question as to what part, in these disappointments of hoped-for success, is played by the forces of energy, intelligence, and luck. But there can be no doubt that the amount and intensity of energy brought to bear upon the problems of a novel undertaking are determinant of its fate.

From the point of view of energy, there are two extreme types or varieties of human beings. There is the type which is easily fatigued and quickly discouraged, the low energy type. It contrasts sharply with the type which is indefatigable and undiscourageable, the high energy type, moving on to its goals because its dynamic voltage can function to overcome obstacles. In between these two groups are the intermediate types who have stretches of various amounts of energy alternating with periods of inertia.

Most common are the people who complain perpetually of being depleted, of being fatigued morning, noon, and night, after a night's rest and after the week-end interim from labour. They are the people that have that 'always tired' feeling. When combined with irritability, these sufferers from fatigability are put down, by themselves, their friends, or even their physicians, as 'neurasthenics'. Envying the live-wire dynamos, who outdistance them in the competitive economy and social struggle, they sometimes castigate themselves, quite futilely, as victims of 'laziness' or 'lack of will-power'.

Physicists have not agreed upon the nature of energy. All they have been able to do has been to define energy as the capacity to do work and to measure it in its various transformations. But psychologically, energy manifests itself as

an urge to activity, a craving for movement, which may or may not have a directed, easily recognized end. When psychic energy is directed toward a definite goal or desire, it has been spoken of as libido. Like every other form of energy—light, heat, or electricity—the drive of libido consists of two factors, an intensity factor and a quantity factor. Each of these is affected by food and the endocrine glands.

Energy of the bodymind is fundamentally a matter of the carbon metabolism and, in particular, of the sugar metabolism. And in seeking to understand the different types of energetic personalities, defective or superabundant, it is necessary to ascertain the individual peculiarities of the sugar chemistry. As a result of such an analysis, it becomes possible to control the production and output of energy, with results consequently appreciable in the activities of the individual.

The Source of Energy

Fat and sugar are the important carbon-containing foods. And because they are the carbon-containing foods, they are the energy-providing foods. For their carbon is burned slowly to form carbon dioxide, with energy set free as a by-product. The process is entirely analogous to what happens in the combustion of coal, black carbon, which is the residue of an anciently compressed and decomposed carbon-containing plant.

Of the two carboniferous foods, fat and sugar, sugar is the more easily burned because it is naturally more oxidized. That is, it takes less oxygen to set sugar on fire, less of a draught, as it were. In consequence, sugar or carbohydrate is the preferred food for quick energy production, while fat is the food utilized for slower energy mobilization.

Yet it takes a quick fire to start a slower flame—it takes more quickly flaming paper, wood, or oil to start coal burning. So it has become an axiom for students of metabolism that ‘ fat burns in the fire of carbohydrates ’. If the bodymind has trouble in burning sugar, it will have difficulty in burning fat. Hence, disturbances of sugar metabolism generate more obvious effects which are more easily ascertained and segregate themselves as varieties more definitely.

Because fat and sugar are sources of energy, the fuel of metabolism, the organism, has developed a capacity to store them. That fat is saved as a result of surplus nutrition,

which is used when there is a deficiency of food, has been observed and practically applied by the earliest domesticators of animals. That sugar is so conserved and mobilized at need is much more recently familiar, being in fact a classic contribution of Claude Bernard, the French physiologist, who, with Lavoisier, and Pasteur, his countrymen, has set the ideals for all advance in medicine. It was about the middle of the nineteenth century, less than a hundred years ago, that he discovered that the liver contained glycogen, animal starch, a compactly storable form of glucose, the sugar which is the favourite sweet of protoplasm. Many studies have since been made of the liver as the body's banker of sugar. Inquiries have been made as to what controls the deposit of sugar as glycogen in the liver. Also as to what regulates the release of glucose from glycogen, and how it is burned where it is burned, the consequences of its burning, the possibilities of its restitution, and the interferences that may arise in the various steps involved.

In the course of the inquiries, many fascinating raids have occurred into the domain of the glands of internal secretion. From the practical point of view, these researches have circled about the most prevalent disease of sugar metabolism, diabetes mellitus. Diabetes mellitus is so-called because the urine contains sugar that is sweet in contrast to diabetes insipidus, where the urine is insipid. Innumerable problems suggested by the clinical phenomena of the disease have provided the starting-point for the most fruitful laboratory investigations. Of these, the triumphant inspiration of Frederick Banting stands at the head as the for-ever-to-be-renowned trapper of the substance insulin, which is to sugar metabolism what gold is to the money exchanges of the world. This comparison is distinctly unflattering to insulin, since gold will undoubtedly some day be displaced as the supreme medium of exchange in the fiscal economics of society by the inventive genius of the economist or even the chemist. Insulin will remain for ever central and dominant in the sugar economics of the bodymind.

The Types of Sugar Metabolism

A number of forces in the bodymind regulate the amount of sugar in the blood, the liver, and the muscles. And it must never be forgotten that the heart and diaphragm are

muscles, very much dependent upon their supply of sugar. One of these always regulates the whole by setting a pace for the others to follow. And depending upon the dominant regulator, types of sugar metabolism may be described.

To begin with, there are the true sugar-lovers—the individuals whose cells prefer to burn sugar when offered a choice of sugar, fat, or protein as in the ordinary meal. These may be called the 'glycophiles'. Contrasted with them are those who would rather burn fat or protein when mixed with sugar. These might be called 'glycophobes'. By methods of determining these preferences of metabolism, the glycophiles and the glycophobes may be definitely separated as characteristic classes of human beings.

Then there are the people who tend regularly to have a high blood sugar, that is an amount of sugar in the blood consistently above the average. These may be classified as 'hyperglycaemic' people. At the opposite pole of the scale of sugar classification are the people who have a blood sugar considerably below the average, who may be labelled the 'subglycaemic'. The glycophiles are generally hyperglycaemic when in good health, the glycophobes are subglycaemic when the individual is apparently well. The hyperglycaemic glycophiles are generally energetic and indefatigable. The subglycaemic glycophobes are lethargic and easily fatigable as a rule. These principles can be understood when one acquires some insight into the relation of sugar to activity (which means muscular movement), behaviour, and fatigue.

The essential difference between the glycophiles and the glycophobes is the speed of development of a sugar deficiency in the body, and a consequent interference with the chemistry of the nervous system. By direct measurement it can be shown that different individuals exhaust their sugar reserve at markedly various rates, which rates decide their resistance to fatigue. Certain of these measurements have been made on fairly large groups exposed to the same tasks and a comparison of reactions has been possible.

A Test of the Types

In April, 1924, for instance, a set of runners participated in a marathon race held in Boston, Mass. Each of the participants had a blood-sugar determination before and after he ran the race. It was found that the man who won the race

had almost as high a blood sugar when he finished the race as when he began. Likewise, the other runners who were in the best condition at the end of the race and came in among the first were those who were high in blood sugar.

The condition and position of the winners contrasted strikingly with those who finished in a poor condition and position in the race. Of the latter, the sugar content of the blood was found to be definitely diminished, and more or less in proportion to their final place in the contest. Of those who were exhausted, four presented a picture of shock very much like that of the sugar deficiency accompanying the action of an overdose of insulin, which lowers the sugar content of the blood.

The next year, 1925, in April, another marathon was run with the same participants. This time it was decided to use what had been learned concerning the limited sugar reserve of certain of the runners. During the training period preceding the race, their blood-sugar content was studied at various intervals along the distance to be covered. It was found, for instance, that it was between the fourteenth and eighteenth miles that there was a marked drop in the blood sugar in those susceptible, accompanied by a feeling of hunger and weakness. If a quantity of sugar was taken just before starting, and in addition during the race, the blood sugar did not decrease and exhaustion did not occur.

The runners who had failed so miserably the year before, and who had passed into a state of extreme fatigue or even collapse, were therefore given a high sugar diet before the race. They were also advised to take sugar along with them as they ran and to eat it as soon as distressing symptoms of any sort made their appearance. Those who were known to develop their symptoms of weakness at definite points in the course were told to take their sugar one or two miles before.

The results were remarkable enough. The blood sugar of all those who took part in the 1925 race was about normal at the end, and all were in good condition. Three of the runners who had done badly in the 1924 race, becoming exhausted, made much better time and attained a higher position. Four of those who completed the race in 1924, in a state of collapse, came through the 1925 struggle without much perceptible difficulty. One participant who

became exhausted between the tenth and twelfth miles expressed a desire to give up then and there. He was given tea and candy, continued, made one other request for candy, and completed the marathon. To the inquiry as to how he was affected by the sugar, he answered, 'Fine, except for weakness and starvation, but felt better after eating the candy.' Others said, 'I couldn't have done without the candies on a bet'; and, 'If I hadn't eaten the candies, I couldn't have finished'; and, 'Every time I ate a piece of candy, I felt fresh.'

A runner who had not competed in 1924, and who was not studied during the training period preceding the 1925 race, had abstained from sugar and potato while privately training himself. At the start of the race he seemed in good condition. He began to slow down and appeared about to collapse as he passed the second station. At the third station, he was given an orange and some candy, and after consuming them his running improved. After a short time, though, he began to run poorly and finished in very bad shape, his blood showing the deficiency of sugar characteristic of his state of exhaustion. He said afterwards that the only part of the last sixteen miles he covered with a sense of adequacy was the short period following the consumption of the orange and candy.

All the observations emphasized that the rank of the men in the race and their physical condition at the end of it was a direct expression of their ability to withstand fatigue by means of their sugar reserve and their ability to maintain a certain level of glucose in the blood, upon which the working muscles fed as they ran. No better illustration could be given of the relation of sugar metabolism to a particular trait, fatigability, and the different varieties of sugar metabolism than the differences exhibited by these men. The tendency to develop or resist sugar deficiency with effort may be regarded as an important indicator of an important aspect of character, the aspect of endurance.

Endurance is the Ability to Burn Sugar

Character, then, is a function of the individual's ability to oxidize energy-providing foods quickly and in sufficient amount. This is true, at any rate, for those manifestations of character which are tested in effort of any sort, popularly

known as endurance. Primarily, the energy comes from the reserve sugar or animal starch, glycogen, of which there is about one hundred and fifty grammes in the liver, and about the same amount in the muscles, when the individual is at rest after a meal. About three hundred grammes of sugar reserve exists, therefore, in the average person, which is the equivalent of about twelve hundred calories.

Now, that glycogen is consumed by muscular activity may be demonstrated in various ways. The simplest is to determine the total amount of glycogen in the liver and muscles before and after work in two animals of similar size and condition. One, for instance, strong and well nourished, weighing about forty-five kilos, pulled a cart for nine and one-half hours. Its tissues averaged about 1·16 grammes of glycogen per kilogram of body weight. A comparison was made of the effect of rest with starvation and the effect of work upon the glycogen content of the body of similar dogs. It took four weeks of starvation to reduce the glycogen to 1·5 grammes per kilogram, which is still more than what remained after a little less than ten hours of work. Work, therefore, requires much more sugar than simple maintenance of the bodymind.

Even at rest, though, sugar is expended by the muscles. This can be shown by the experiment of cutting the motor nerves which supply the muscles of one leg of an animal. This deprives those leg muscles of nervous impulses which are their tonic, keeping them in a state of readiness or tension for action. After a time, the glycogen content of these nerveless muscles can be compared with that of the intact muscles of the other leg. In one such experiment, that of Mancuse, the average glycogen of the control muscles was about 50 per cent less than that of the operated. Glycogen obviously had accumulated in the latter as an effect of disuse. That relaxed people burn less glycogen than tense people is another conclusion to be drawn from this experiment. Also, that people who tend to be more tense should consume more sugar, if tests prove that they have the ability to burn it.

Antarctic Explorer's Disease

One of the classical discoveries of the field of muscle chemistry was that of Voit when he showed that under ordinary conditions all the energy expended in behaviour or activity originates in non-protein substances; that is, sugar

primarily, and fat secondarily. He found that there was no increase in the nitrogen excretion when a dog on a mixed diet was worked in a treadmill. The protein metabolism takes its course during work, independently, as if entirely unaffected by the vast changes in energy production occurring as the bodymind labours.

Yet, if there is an insufficient supply of sugar, protein is diverted to the uses of energy production. Then, as Kellner showed, there is a concomitant increase in the nitrogen output corresponding to the protein thus destroyed. Individuals, therefore, who have an insufficient sugar metabolism will disturb their protein metabolism when they do physical work. As a result, self-poisoning may occur because of the bizarre use to which the protein is being put.

The protein metabolism of muscles is unique. Muscles contain substances, like the creatins, carnitines, and guanidines, which are poisonous nitrogenous bases. Their production is characteristic of active protein transformations in muscle. Continued muscular activity upon a pure flesh diet is extremely dangerous, as shown by the records of Mawson and Mertz in the Australian Antarctic Expedition of 1912–13.

This expedition was carried on in the severest Antarctic climate and the most difficult ice country in the world. To make progress required taxing the heat- and energy-producing mechanisms to the limit. An accident in a crevasse, three hundred miles from their headquarters, caused them to lose a companion and his sledge, and delayed them so that they found themselves with about a week and a half of food for themselves and none for their dogs. They had to walk back, killing dogs for sustenance, the flesh being naturally exceedingly lean and glycogen-poor. After days, Mertz began to break down, developed weakness of the muscles, and complained of severe pain in the abdomen. Mawson also had violent abdominal cramps. Mertz expressed great aversion to the dog meat. After another seven days, Mertz displayed symptoms of poisoning of the central nervous system. Mawson kept a diary.

January 7. It was a sad blow to me to find that Mertz was in a weak state and required keeping in and out of his bag. He needed rest for a few hours at least before he could think of travelling. I have to turn in again to kill time and also to keep warm, for I feel the cold very much now.

At 10 a.m. I get up to dress Xavier, but I find him in a kind of fit. Coming round a few minutes later, he exchanged a few words and did not seem to realize that anything had happened. . . . During the afternoon he had several more fits, then became delirious and talked incoherently until midnight, when he appeared to fall off into a peaceful slumber. . . . After a couple of hours, having felt no movement from my companion, I stretched an arm and found that he was stiff.

Mertz was poisoned by the effects upon his nervous system of a high protein diet, unable to maintain the normal mechanism of acid neutralization in functioning muscles. That Sir Douglas Mawson lived to tell the tale in his book, *The Home of the Blizzard*, published in 1915, is in itself significant of how differently human beings react to the same food intake, one being killed by it, and the other merely suffering abdominal cramps. The difference was probably due to the fact that they functioned as quite different varieties of metabolism.

The Ideal Diet for Athletic Training

Such considerations and experiences show that a high protein diet as a preparation for muscular effect and endurance, such as steaks and chops for athletes, is wrong for certain human beings. On the other hand, it may be quite all right for others. No generalization is possible unless the different ductless glands and their relation to types of protein metabolism are considered. But it may be noted here that one effect which must be respected is the effect of meat upon the heat metabolism. Persons already functioning on a high level of heat production will tend to have an increased heat production, since meat stimulates oxygen consumption. So they will have greater *difficulty* in regulating their heat metabolism. Workers naturally functioning at a low level of heat production will be benefited by high protein food and be warmed by it.

Nevertheless, it is worth noting that on a high protein diet the muscles function most efficiently as machines. That is, they produce more work and less heat per pound of weight. In a dog fed on meat alone, Pfluger found the largest work-heat ratio ever obtained, almost 50 per cent of the heat value of the food being converted into work. Ordinarily, on a mixed diet, mostly carbohydrate, the work-heat ratio is only about 20 per cent. It has been concluded by Robertson

that for a short period of intensive effort, as the ' dash ' of one hundred yards, a high protein diet is advantageous. But for prolonged activity, an abundant proportion of sugar or starch must be mixed with the protein.

Paralleling the consumption of sugar as glycogen in the muscle cells, the destructive side of the chemistry of work, there is a constructive side. As a result of activity, new substances are formed with fresh problems for the cells. Acids are evolved, lactic acid and phosphoric acid, which tend to poison the muscle and blood by an acidosis. This acidosis is responsible for the fatigue of exertion and the need for rest and sleep afterwards. With rest, sugar and a sugar-phosphate compound are re-formed out of the lactic acid and phosphoric acid. This is a typical case of a circular reaction, evolving energy, with a utilization of the wastes to make again the original substance. It is an achievement that might be envied by the efficiency engineers investigating a chemical plant.

Sugar and the Brain

Sugar provides energy not only for muscles. It also provides energy for the functioning of the spinal cord and the brain. It has been shown by Winterstein, of Breslau, that the isolated central nervous system of the frog consumes sugar from a surrounding medium just as does the beating heart. But, in the case of the beating heart (typical of functioning muscles), a large increase of oxygen consumption and carbon production accompanies the utilization of the sugar. There is only a small increase of oxygen intake in the case of the nervous tissue.

It follows that a different set of chemical reactions are involved in the sugar reactions generating energy in the brain cells. Thus, it has been shown that the brain can live upon the lactic acid which poisons muscle cells. Recently, it has been proved by Myerson and his associates that the blood of the veins going from the brain contains less sugar and is more acid than the blood in the artery going to the brain. This tends to prove that there is a consumption of sugar during brain activity. But there is no consequent acidosis like that of muscle activity. At any rate, there has been established the importance of sugar for the functioning of the brain. It is interesting to note that diabetic children who have difficulty in burning sugar in their muscles

nevertheless generally stand high in their school studies, and are definitely superior in intelligence tests. This is additional evidence that the sugar of the brain passes through a chemistry different from that of the muscles.

Mental Insulin Reactions

According to all evidence available, the dominant catalyst and glandular regulator of sugar metabolism is insulin, the internal secretion of the islands of Langerhans in the pancreas. Insulin increases the ability of cells to absorb sugar from the blood and to burn it for energy. In this way insulin may lower the sugar content of the blood to even below the normal —the condition of sugar deficiency called hypoglycaemia.

Various mental symptoms may appear as the blood sugar drops, apparently because of a deficiency of sugar for the immediate needs of the tissues. There may be a feeling of nervousness accompanied by tremulousness, a feeling of weakness or even exhaustion, with or without a gnawing hunger for food. These feelings have been best described by diabetic patients to whom insulin had been given to reduce their high blood sugar to more normal levels. Their symptoms are various, but may be generalized as follows:

The level at which a patient becomes aware of the fall in blood sugar is usually fairly constant for that individual. The normal blood sugar is about one hundred milligrams per one hundred cubic centimetres of blood. When a reaction has already been experienced, the onset of a subsequent one is usually recognized by the patient when the blood-sugar percentage falls to some point between eighty milligrams and seventy milligrams. Usually this is rapidly followed by definite signs—most frequently a sweat which may be profuse; pallor and flushing are common; sometimes a change in pulse rate. In children this increased pulse rate is often the means of detecting hypoglycaemia; in adults, the sweat is the outstanding feature.

At the same time, the subjective symptoms become more severe; the feeling of nervousness may become extreme anxiety or uncontrollable emotional excitement. There may be a feeling of tremulousness with manifestations of disturbances of co-ordination. Patients have shown a loss of power to perform fine movements with their fingers. Actual tremor has not been observed at this stage. At times, there is a

feeling of heat or cold, sometimes of faintness. Vertigo may be marked, or there may be a complaint of seeing double. This is the extent of most reactions, when the blood sugar has been lowered to between 0·07 per cent and 0·05 per cent.

Much more severe manifestations are observed with further lowering of the blood sugar. Unmotivated excitement to the point of mania, delirium, disorientation, confusion, and aphasia have all been observed. 'With the greater possibility of detecting the onset of symptoms in man, because those of a subjective nature can be self-observed, the degree of hypoglycaemia at which they first make their appearance is much less than in laboratory animals. This level varies, however, in different individuals. There are patients who become aware of the hypoglycaemia when the blood sugar is between eighty milligrams and ninety milligrams. On the other hand, other patients have experienced no symptoms at levels as low as fifty-four milligrams. A severe reaction has been observed with a blood sugar sixty milligrams, and a determination of forty milligrams has been obtained during the course of a milk reaction. A blood-sugar percentage of thirty-five milligrams is usually accompanied by unconsciousness. The lowest blood sugar observed was twenty-five milligrams per hundred cubic centimetres. This is just about one-fourth of the normal.' (Fletcher and Campbell.)

Certain bizarre reactions have been narrated by some patients. One, a patient of Foster, recorded the following which reminds one of some of the powers and tendencies possessed by the hero of Philip Wylie's story, *Gladiator*, who was endowed with a superhuman muscular strength that enabled him to throw large cannon for long distances and to make holes in brick walls with one crash of his fist :

Then came a day when I felt that I ought to clean up our share of the beach. I worked at this for an afternoon, came home wearied, and after supper went for a short stroll with the three children. When the moment came for our return—about seven—somehow I could not order myself to return. Instead, I was in a sort of hazy, half-imagined, half-real world. I was possessed with a sudden release from all fatigue and with an overwhelming desire to leap and shout. That comprised acting like a damn fool, and I knew it, but I could not restrain the impulse. I surprised and amused the children by tossing them into the air and deftly catching them again. I was drunk with an indescribable excess

of physical strength and an utterly uncontrollable urge to use it. Darkness was upon us when at last I managed to turn my unwilling feet homeward. Mrs. R. sensed something awry upon our arrival, but could not decide just what was wrong. She put the children to bed and then came down to me in our living-room. I was lying on a couch, trying with my oddly fuddled brain to fathom it all. Suddenly I was seized with the impulse to fling my glasses through the wall of the house, to leap up and pull the fireplace to pieces, to toss the furniture like so much straw through the roof—anything to give vent to the throbbing power which surged mightily through my muscles. With bursts of shouts and laughs and grunts, I wrestled with the house and its appointments, finally flinging myself through and down the lawn toward the sea. Mrs. R., terror-stricken, followed, and when she came to quiet me, I seized her and, with the affectionate gentleness of a bear, nearly squeezed the life out of her. I knew she was terribly frightened ; I wanted to reassure her ; but merely to attempt reassurance was to set off again the rush of the uncontrollable power within me. At last, somewhat exhausted, in a lull between the onsets, I lay again on the couch and she managed to get sugar and orange juice into me. That ended the show.

I have described the first shock in some detail because all of its successors have been like it—only the setting has been changed. I have had this type of shock while at bridge with friends, when my sudden blood-curdling burst of grunts so startled them that some could not remember seeing me hurdle the bridge table. I have had them on such occasions as Christmas Eve after the Santa Claus job at the tree was done and exhaustion was upon me—when I had gone to put coal on the furnace for the night and instead threw the coal all over the cellar and tried to beat my shovel into a ploughshare. I have had them in the middle of a quiet evening of reading—suddenly upon me and hell let loose. Upon one occasion, I had one directly after another. To check the first, I ate, among other things, two tablespoonfuls of sugar and a large quarter of a highly sweetened blueberry pie. Twenty minutes later the shock had returned.

The symptoms of the approach of this type of shock have been in my case (1) failure of my eyes to retain focus when reading and inability to grasp what is being read ; (2) a deep depression—vague and unaccounted for by any known facts of experience, coupled with the bitter desire to seek its cause ; (3) in conversation, the sudden loss of ' the thread of the discourse '—either leaving a thought unfinished or eventually completing it after long pauses or jumping from one intervening subject to another—a dead give-away to my wife, who knows my way of speech ; (4) when speaking calmly upon any dull subject or otherwise, the sudden desire to burst into loud gustos of vocal volume, usually

resulting in sounds such as might come from a speaker who had been violently and repeatedly slapped upon the back. The final signal before the storm is a sudden welling-up to the bursting point of a torrent of physical power which seeps through and unleashes itself from all control—there is no mastering this; I have deliberately tried it, whipping my will to check the torrent, but I have never succeeded; the unintentional pressure of my fingers upon the arm of my chair may be the spark; my fingers leap to the grip and away through me speeds the energy, while my fingers are trying to crush the wooden arm, and in this flood of muscular energy the facial muscles, also, are touched to try their best to twist and stretch.

As I have told you before, when I first enjoyed this novel experience, my sole worry was concerned with the state of my brain. I feared that somehow I was surely going mad.

This type of hypoglycaemic reaction or insulin shock suggests that there may be some individuals whose remarkable muscular powers are dependent upon some such peculiarity of insulin supply or reserve. Some of the highly energetic people who seem capable of driving themselves to any lengths may be a physiologically insulin-rich variety of human being.

The insulin reaction is dependent upon at least three factors which can be investigated and controlled. First, there is the matter of being well fed, which means an adequate amount of glycogen in the liver. The insulin reaction occurs the more readily, the less the glycogen content of the liver. Secondly, there is the state of thyroidism of the individual. The more thyroid is functioning in his liver, the more easily released and converted into sugar is the glycogen of the liver. Thyroid fed to a diabetic in the proper amounts may protect him against insulin shock. Thirdly, the total acid or alkaline effect of the diet has an important influence. Animals kept on an acid-forming ration of oats and bread are more refractory to insulin than those kept on a base-forming one of oats, carrots, and cabbage.

The Respiratory Quotient of the Different Types

For the carbon-containing foods, sugar, fat, or protein, to burn completely into water and carbon dioxide, sufficient oxygen must be available for their carbon and their hydrogen. The fire of life produces water by the addition of oxygen to hydrogen and converts carbon into carbon dioxide by uniting it with oxygen.

Now, there is enough oxygen and hydrogen in sugar to make possible their combination into water without any outside source of oxygen. Hence the name carbohydrate, which means carbon plus a hydrate ; that is, hydrogen and oxygen in the proportions making water, two of hydrogen and one of oxygen. A hydrate is any compound in which two parts of hydrogen are present to every one part of oxygen.

When sugar alone is burned in the bodymind, the oxygen consumed is exactly accounted for by the oxygen in the carbon dioxide produced, since all the extra oxygen breathed in is consumed in the combustion of the carbon. Now, the name 'respiratory quotient' has been given to the ratio between the oxygen supplied from the outside, or inhaled, to that in the carbon dioxide exhaled in a given period of time. The respiratory quotient of sugar, or the ratio of the volume of oxygen inhaled, divided by the oxygen of the carbon dioxide exhaled, thus is bound to be one of unity, since they are exactly equivalent, for carbon dioxide can be formed only by the addition of just enough oxygen to burn the carbon.

If we measure the oxygen consumed, as can be done in any ordinary basal metabolism test, and the carbon dioxide, as can be done with a suitable attachment to the ordinary basal metabolism test, the respiratory quotient can be directly determined. For convenience the respiratory quotient is abbreviated as the R.Q. The R.Q. simply states numerically how much of the oxygen of the air, which is being constantly inspired and consumed, is used in the burning of carbon, and by inference how much is consumed in the burning of hydrogen.

Now, fat contains much less oxygen proportionately than does sugar. Consequently, it will take much more oxygen to burn it completely. A certain amount of oxygen will have to be used in burning its hydrogen, which makes its respiratory quotient less than one, since not all of the oxygen it consumes will be employed for its carbon. Actually only about seven-tenths of the oxygen it consumes will go toward its carbon, the other three-tenths being necessary for the combustion of the hydrogen. So that the respiratory quotient of fat is about 0·7 instead of 1·0, which it is for sugar.

Protein is intermediate in position between sugar and fat as regards the amount of oxygen used to burn its carbon

completely. About eight-tenths of the oxygen used in the burning of protein will go toward the production of carbon dioxide. Hence its respiratory quotient is 0·8.

These figures of the respiratory quotient, when determined under standard conditions in a particular individual, will tell us just what sort of food his cells are burning or prefer burning. For instance, if a basal metabolism determination is done and the respiratory quotient turns out to be 1, we may be sure that the individual is maintaining his heat or body temperature by means of the energy resulting from the combustion of sugar. If the respiratory quotient is 0·7, it is positive that he is burning fat. If it is 0·8, we know that he is burning protein. If it is between 0·7 and 0·8, we know that he is burning a mixture of fat and protein. If it is between 0·8 and 1·0, we know that he is burning a mixture of protein and sugar, or of fat, protein, and sugar, depending upon the exact figure.

Sometimes the figure is above 1, when sugar is converted into fat, which is the result of a reduction process, the opposite of an oxidation. The fat formed from the sugar contains less oxygen than the sugar, and oxygen is set free. This oxygen can be used in further combustion, thus sparing some of the externally added oxygen to be added to carbon, and the respiratory quotient is raised above 1. This occurs, for instance, in hibernating animals, such as the squirrel in the autumn, when they are feeding themselves sugar-rich foods, preparing for the winter by a process of self-fattening. On the other hand, the quotient is lowered when fat or protein is converted into sugar, since oxygen must be added for the transformation, sugar containing much more oxygen than either fat or protein ; which is what happens to the hibernators during the spring before they awaken.

Not only is it thus possible to say just what foodstuff is being burned at any particular time in the body and how, but also how much of it, by determining at the same time the nitrogen excretion. The nitrogen excretion tells how much protein has been burned, since the nitrogen comes from the protein and bears a definite proportion to it. It can be used to determine the amino-acid contribution to the energy production during the period of observation. In this way, an exact analysis of the energy process of a given individual is possible.

The respiratory quotient can be employed as a rapid means of diagnosing the types of the two sugar varieties of metabolism, the glycophiles and glycophobes. The respiratory quotient is determined after a night's rest and on an empty stomach. A standard quantity of sugar is then given. If the individual is a glycophile—that is, if his bodymind utilizes sugar readily and easily—the respiratory quotient rises quickly to 1. If he is a glycophobe—that is, if he burns sugar only with difficulty—the respiratory quotient will rise only part of the way toward 1. If he is a diabetic or a potential diabetic, it may not rise at all, or even decline. Thus is provided a fairly quick way of approaching the problem of classifying the individual from the point of view of his capacity to burn sugar.

And, indeed, the same principle may be applied to the determination of his capacity to burn fat and to burn protein. If his respiratory quotient quickly becomes 0·7 when he is offered a meal of fat, then his capacity to burn fat is good. If not, it is poor. If he is given a high protein or pure protein meal, and his R.Q. quickly becomes 0·8, he has a good capacity to burn protein, and *vice versa*. And if he is given a mixed meal of definite portions of sugar, fat, and protein, the determination of his respiratory quotient enables one to place him as regards his special tendencies or special abilities to burn food for energy. These, of course, are general principles, used when other important considerations do not have to be taken into account.

The Three Variables of the Sugar Types

In classifying individuals, then, from the point of view of their sugar metabolism, three variable criteria have to be considered. First, there is the fasting blood-sugar level, which furnishes an indication of the amount of raw sugar available to the tissues, the muscles, and the nervous system. Individuals range themselves from the low sugar types, the hypoglycaemics, through the average normal to the high sugar or hyperglycaemic varieties. In general the low sugar types are the glycophobes, the high sugar the glycophiles. Second, is the reaction of the respiratory quotient to the ingestion of sugar. Here again present themselves the types which react slowly, not showing much preference for sugar, ranging through the average normal to the individuals who react

quickly. And again, in general, the slowly reacting types, the glycophobes, correspond to the hypoglycaemic, while the quickly reacting ones, the glycophiles, correspond to the hyperglycaemic.

Third variable to consider and to measure is the sugar tolerance—that is, the total standard amount of sugar a given bodymind may absorb, burn, or store. Sugar tolerance may be determined in two ways. One is to give a standard quantity of sugar and observe whether there is an overflow from the blood through the kidneys into the urine. This is called the method of testing the alimentary glycosuria. Of the different sugars that might be used, glucose has not turned out to be as valuable as galactose for this purpose, as too large quantities of the former have to be administered to make the test as safe and as comfortable as it should be. But galactose registers significant results in relatively small quantities. The other method is the use of the blood-sugar curve after galactose feeding. An accurate determination of capillary blood sugar can be made by taking a few drops of blood. If thirty grammes of galactose are administered, the blood sugar increases, normally, to a maximum in half an hour. If it maintains this maximum beyond an hour, an abnormality of the sugar metabolism is established. Blood is, therefore, taken at intervals of one half-hour, one hour, and two hours, and a curve constructed. In diabetes or diabetes-like conditions of metabolism, the plateau of sugar increase is maintained for several hours beyond the normal high point. In general, the results of tests of alimentary glycosuria correspond to the curves of blood-sugar tolerance. But the blood-sugar curve is the more delicate indicator of the time necessary to burn the extra sugar.

Summary of Sugar Types

The laws of the classification of sugar types and the prescription of scientific diets for them may be postulated as follows:

1. If the individual has a high sugar tolerance, he will maintain a high blood sugar for hours after a sugar or mixed carbohydrate meal, with a low R.Q., without any of the sugar overflowing into the urine. This is generally true of the types I have described as the glycophobes.

2. If the individual glycophile has a low sugar tolerance,

he will maintain a high blood sugar after a sugar or carbohydrate meal for a much shorter time. If he exceeds his limit quickly, sugar appearing in the urine when he does so, he is a prediabetic, and not a glycophile. The glycophiles may have a high sugar tolerance, when their glycogen stores have been depleted by improper feeding or exercise. The sugar then does not increase the glucose content of the blood, but is stored immediately as regenerated glycogen. But these individuals will show a high R.Q.

3. In prescribing the amount and kind of sugar to be taken in a diet, the fasting blood sugar, the blood curve, the urinary tolerance, and the response of the respiratory quotient of metabolism to sugar under standardized conditions provide the means of gauging accurately an individual's capacity and type.

4. If he tends to become blood sugar low or to run a low blood sugar even though his tolerance and his ability to burn sugar are good, as shown by the R.Q., he should be fed large quantities of easily absorbable sugar, such as honey, corn syrup, or chocolate frequently.

5. If he tends to become blood sugar low with impaired tolerance of sugar and retarded rise of the respiratory quotient, he should be fed no sugar at all, but starches, such as bananas, oatmeal, and the other cereals, rather than the concentrated glucose-containing foods.

6. If he runs a high blood sugar with adequate tolerance and adequate reaction of the respiratory quotient, he can be given large quantities of both sugars and starches.

7. If he runs a high blood sugar with impairment of tolerance and a normal or subnormal respiratory quotient, his sugar intake must become zero and his starch intake adapted to the limit of his tolerance, with or without the use of insulin.

8. In individuals who have a low blood sugar accompanied by low basal metabolism, but a normal respiratory quotient and a normal tolerance, the extracts of the adrenal glands, either of the cortex or of the medulla, adrenalin, or both, are of value when administered with sugar.

In certain types with a low blood sugar, there is present a tendency to produce an excess of insulin in response to intake of sugar. They should be given a high fat, rather than a high sugar, diet. Enough starch should be combined with the fat to prevent the development of acidosis.

The metabolism of fats is so intimately connected with that of carbohydrate that it must be considered whenever the sugar quota of a diet is being worked out. Every diet must contain a blend of sugar and fat in proportions suitable to the individual constitution. In addition to the principles developed, in typing the sugar requirement, it is now necessary to emphasize the role of the fats (fatty acids) in determining personality characteristics and food needs.

CHAPTER IX

FATS, ACIDOSIS, AND THE PHLEGMATIC CHARACTER

THAT there are people whose metabolism obviously rotates around their disability to dispose of fat, their tendency to turn their food into fat, to become and look overfed, is one of the common facts of experience. It is, indeed, the only fact of metabolism universally known. That there is an association between fat and mental state, the dominating mood and attitude of the individual, is a common obsession of folk-lore. Most quoted in this association is Caesar's physiognomical diagnosis of Cassius :

> Let me have men about me that are fat ;
> Sleek-headed men, and such as sleep o' nights ;
> Yond' Cassius has a lean and hungry look ;
> He thinks too much ; such men are dangerous.

Is fat necessary for normal nutrition ? Is it necessary for special types of personality ? What special glandular constitutions exhibit disturbances of fat chemistry which enable us to segregate them as types ? Who should eat fats and how much ? What are the mental and emotional effects to be expected ? These are some of the questions that at once arise as soon as one asks one's self : What part does fat play in the development and modification of individuality ?

Until quite recently it was pretty generally accepted, both as a result of animal experiments on fat-free diets supplemented by Vitamin A and D, and as a consequence of the fact that sugar can be converted into fat in the animal organism, that one could remain healthy and normally functioning in every respect on a fat-free diet, provided an equivalent amount of sugar or protein, to furnish calories, was present in the meals. In the last two years, Burr and his associates have shown that an absence or deficiency of fats of the type

of linoleic acid—that is, *unsaturated* fatty acids—will be reflected after a time in an impairment of health and efficiency. The symptoms in animals of such fatty acid starvation are serious. A certain amount of fat containing these unsaturated fatty acids, as olive oil, corn oil, poppy-seed oil, or linseed oil, must therefore be a part of every diet.

When the tissues are supplied with a greater amount of fat than they can burn, the fat is stored. And, as is well known, fat is the great reserve food, reserved, that is, only as material to be burned to supply energy for heat and the other necessities of running the body. For fat is by no means a complete food. If the body is forced to live upon its own fat for a time, as occurs in starvation, short or prolonged, a disturbance of metabolism results. This is an acid poisoning or intoxication, the form of acidosis called 'ketosis' because it is due to the accumulation of incompletely burned fats and their by-products, the ketonic substances, of which acetone is the best known. Certain individuals, most markedly in their childhood, but maintaining the tendency somewhat all their lives, develop an acidosis or ketosis quickly under strain because they have a limited capacity to handle fat. The consideration of these acidotic types involves an analysis of the role played by acids in the evolution of individuals.

Acidity, the Enemy of Life

All living cells form acids during the course of their chemistry. These acids it is imperative for them to remove or change, in order to render them innocuous, to prevent being poisoned by them. The devices evolved to deal with acids, or to regulate the production, distribution, and elimination of acids, are among the most interesting of the functions that can be studied in man, animals, and plants. Life and death, health and sickness, may, indeed, be said to be dependent upon them. The antidotes for acids, the alkalis, are used to neutralize them as carefully by the living organism as by the most pedantic routineering analytical chemist. Indeed, no analyst could deal with his acids more carefully because the body regulates itself by reacting to differences in acidity which are not perceptible to the ordinary chemist's reagents.

There are no absolutely neutral solutions or fluids. Even

the purest water is ever so slightly acid. This acidity is one one-hundred millionth of a per cent, a veritable homoeopathic acidity, a chemist's trace of acidity, it might be called. The normal acidity or alkalinity of the body and its fluids—typically the blood—varies within the range of dimensions of similar calibre and is virtually a neutrality comparable to that of pure water.

The normal chemical reactions of the body are included in a most narrow spectrum of acidities and alkalinities. Beyond the pale of minute fluctuation in acidity or alkalinity lie disease and death. An elaborate system exists to maintain this quasi-neutrality within the vital fluids by controlling the acid-base balance.

There are at least three reasons for this necessity for constancy in reaction. First, fatty acid will oxidize completely in the presence of burning sugar only within that range—acidosis or ketosis, the incomplete combustion of fat, resulting if acidity is provoked outside the limits of variation. Second, the optimal concentration of calcium ions, prerequisites for healthy irritability of the cells, including the nervous system, is also dependent upon it. And thirdly, it is the fundamental constant for the maintenance of all other constant characteristic chemical constituents of the blood and tissues—the amount of sugar, phosphate, carbonate, etc. For they would be and inevitably are disturbed by any disturbance of the acid-alkali balance.

Now, during the constantly occurring chemical reactions of the cells, and pre-eminently because of the continuous feeding of the fires of life by oxidations, acids are regularly produced in the healthiest of bodies. Carbonic acid, phosphoric acid, sulphuric acid, lactic acid, oxalic acid are formed in us every second of our existence, but they are not allowed to accumulate. They are not allowed, indeed, to exist for more than for the very moment of their formation. For they are at once transformed, changed, not into a state of innocuous desuetude, but of useful innocuousness by the action of anti-acid, alkalinizing agents, of which there must always be a great reserve at hand, called ' buffers '.

Thus acidosis is avoided and circumvented. If acidosis is not thus foiled and sugar fails to burn as it should, there is interference with the burning of fatty acid. The incompletely burned fatty acids, the simplest being diacetic acid, add their

quota to the constantly mounting tide, washing away the bulwarks and sandworks of reserve alkali. So long as these can hold and absorb the insidious corrosions of the invaders, the acidosis is said to be compensated. But sooner or later their resistance gives, and an uncompensated acidosis is upon the individual, threatening the stability of his tissues, the fine adjustments of his nervous system, the keen edge of awareness of his mind, and quickly deranging the chemical reactions of his cells to the disorder of death.

A number of mechanisms have been worked out, in the course of evolution, for the diplomatic avoidance of any such issues of acid decompensation. For it is one of the chief chemical problems of the organism to neutralize and remove acid suavely and blandly, without appreciable changing or upsetting of the status of established things in the cellular state. One could imagine that if it were not necessary to maintain exactly the *status quo*, so to speak, some organ might have been evolved long ago, whose function would be to supply alkali directly to the blood for purposes of neutralization, much in the manner of the standard solutions of base used in analytical chemists' laboratories for ordinary titrations. The liver supplies sugar to the blood, whenever the sugar content of the blood is depleted. Why not an organ to supply alkali, whenever the alkali content of the blood is depleted?

One learns again to admire how wise and subtle the organism is in its ways of dealing with its problems. During such titrations as are carried on by the chemist in his test-tubes and beakers or other glassware, when he pours acid into alkali, or alkali into acid, extensive intermediate alterations of acidity and alkalinity occur. Heat is produced, and there can be no talk of constancy of conditions.

To get around this difficulty, the organism makes use of the fact that, in virtue of the laws of ionization, the acid *salts* of a *weak* acid will prevent the acidity of the weak *acid* from becoming effective, by acting as tampons or sponges for the acid. Bicarbonate of soda is a typical sodium salt of a weak acid, carbonic acid, which, when mixed with carbonic acid, will prevent its acidity from making itself effective. It does this by interfering with the action of water upon the weak acid, necessary for it to display its acid power upon things. Acid salts are double-faced and double-dealing and

double-living hybrids which can act quietly to usher acids, their relatives, into an impotent and paralysed state, in which they can be quickly eliminated from the scene, without making a scene. Or, to put it in the technical jargon, the acid salts react with their related acid ions as they form and thus prevent their accumulation by balancing electrolytic dissociation with hydrolytic dissociation.

Bicarbonate of soda or sodium is the chief acid salt buffer in the blood, because carbonic acid, the offspring of the combination of water and carbon dioxide, is the acid produced in maximum quantity and with every breath of metabolism. But for the phosphoric acid there are acid salts of sodium and potassium, the diphosphates. In general the bicarbonates act as the characteristic buffers for the blood plasma or serum in which they are present dissolved in greatest quantity, and the diphosphates are the characteristic buffers of the blood cells, red and white, in which they occur in greatest quantity.

Besides these acid salts which constantly act as buffers against acid, there are other substances capable of leading double lives, and acting as either acids or alkalis, depending upon the demand made upon them. They are known as 'amphoteric' substances. The proteins of the blood are such amphoteric substances and act as a secondary line of defence against acids. The primary line of defence consists of the bicarbonates and the diphosphates. Chief of the protein buffers is haemoglobin, the pigment of red cells, which is really a weak acid in virtue of the presence of the acid radical, haematin, in its chemical constitution. When haemoglobin combines with oxygen there is formed oxy-haemoglobin. The latter is more acid than the former, and combines with alkalis to form basic salts of haemoglobin. These basic salts of haemoglobin combine with about three-quarters of the carbonic acid of the blood continually evolved in metabolism, and transport it to the lungs, where the salt combination is broken up and the carbonic acid exhaled as water and the gas, carbon dioxide.

Acidosis among Children

Acidosis is quite common among children of the upper middle class and the more wealthy. Such children may be designated as 'acidotics'. An acidotic is a child who has

difficulty in oxidizing or burning fatty acids. They have a tendency, under certain conditions, most often when on the wrong diet, to suboxidize or burn incompletely their fats. As a result, there is an accumulation of poisonous, narcotic fatty acids in the blood and tissues.

The parents and forbears of these children are generally of the so-called nervous type who have pursued mentally and emotionally exacting occupations for two or more generations —most often in accumulating a fortune. The children are the offspring of brain workers rather than manual workers. Just what sort of a twist to metabolism is given by such intense activity of the nervous system rather than of the muscular system is one of the fascinating problems of metabolism.

An acidotic child is nearly always below par physically, although often above par mentally, as measured by intelligence tests. He is usually underweight, although he may occasionally be overweight. To the impartial observer (in other words, *not* the parents) the child is obviously overactive, nervously and mentally, and strikes one as precocious in some respects and a retarded infantile in others. Capricious likes and dislikes, appetites, and tendencies appear during activity. When they play, they perspire poorly, and enjoy hot weather rather than cold. They do badly in cold weather and complain bitterly of the low temperature. Their personalities have to be kept wrapped in cotton wool, as it were, during the winter. They suffer much from cold hands and feet.

These children all have a strikingly dry skin which readily becomes scaly or even eczematous, particularly on the scalp, face, and back. They develop one ‘ cold ’ after another during the winter. ‘ Colds ’ which may quickly become an ‘ asthmatic ’ bronchitis are developed by them. They alternate their ‘ colds ’ with attacks of ‘ biliousness ’ or attacks of recurrent vomiting, attacks which may last a day or a week, and may even end fatally. They may have sudden elevations or depressions of temperature, accompanied by a coated tongue and the peculiar ‘ fruity ’ odour of the breath which is characteristic of the accumulation in the blood of the acetone substances, products of the incomplete combustion of fats. They show their intolerance of more than a limited amount of fat even when they are infants, doing badly on rich breast milk or on a cow’s milk formula containing too much fat (for them).

An examination of the urine of these apparently well children, particularly when they are on an ordinary fat-containing diet, may show a slight but constant amount of diacetic acid, which is never present when the fats are being properly burned in the organism. When the metabolism is subjected to strain, as by the trauma of an accident, the excitement of a party or travel, or the fever of an infection, a marked increase of acetone substances in the urine occurs, paralleling the increased difficulty in burning fats. These children may present themselves to the physician because they are subject to recurrent colds, coughs, eczemas, asthmas, or general malnutrition and anaemia. Or they may present themselves because they are so excitable, so fatigable, so subject to tantrums, so spoiled and unmanageable in the home, as to make imperative the consultation with a physician.

To understand the relation of diet to 'physique', 'chemique', 'psychique', 'morbidique', and character in these children—the same phenomena in an exaggerated or changed form plague them when they become adults, and they ultimately evolve one form or another of metabolic disease—it becomes essential to review the part played by acids and alkalis in balanced body chemistry. The tendency to acidosis or its opposite, alkalosis, are important indicators and producers of certain character difficulties.

The Alkaline Reserve Forces

The alkali reserve of the blood is constituted from the three acid salts, the bicarbonate, the diphosphate, and the oxy-haemoglobin. The alkali reserve acts as a sponge for acid, which absorbs acid as it is produced and neutralizes it before it can appreciably upset the acid-base balance of the tissues. The bicarbonate makes up about 5 per cent of the alkali reserve, the diphosphates about 25 per cent, and the haemoglobin about 70 per cent. Although the bicarbonate amounts to a relatively small amount of the alkali reserve, it will register, and therefore mirror, by its adjustments, all changes in the total buffer system.

A determination of the bicarbonate content of the blood is, therefore, the usual way of determining the alkali reserve. A decrease of the bicarbonate accompanies an acidosis; an increase of it parallels an alkalosis. Acidosis or alkalosis are called compensated until the system of adjustment breaks

down, as it must sooner or later. If the vicious circle of acid accumulation or alkali removal is not broken, an uncompensated acidosis or alkalosis presents itself, with death in prospect at any time.

An equilibrium exists between the bicarbonate in the blood and the diphosphate and haemoglobin of the blood cells. These maintain a balance by means of the chlorides of the blood. The chlorides can move quickly from the liquid part of the blood, the plasma, to the solid part, the cells, or from the cells to the plasma, the migration being known as the 'chloride shift'. This chloride shift takes place in the lungs. As carbon dioxide has to be released in the lungs to be exhaled, it first passes into the plasma to combine with sodium and water, forming bicarbonate of soda. On contact with oxygen in the lungs, it breaks up into its constituents, water and carbon dioxide, which are exhaled. The sodium then recombines with the chloride, from which it has been temporarily divorced in order to make possible its union with carbonic acid. Chloride most volatile in its affinities, thus passes from hand to hand, from the blood plasma into the cells and back again. There is a dance of atoms and ions, for which the name of 'chloride shift' seems wholly inadequate, with every breath we take.

The Oxygen Debt

Breathing is thus most important for the quick removal of acid. The amount of carbon dioxide, which means carbonic acid, removed per minute in respiration depends upon how rapidly one is breathing. By varying the rate of breathing, by breathing slowly or fast, a ventilation of acid is achieved. When one becomes more active after a period of rest and thus produces more acid, the rate of breathing is increased to assist the escape of the extra acid generated by extra activity.

Physical exertion floods the blood with the acid products of muscle chemistry, chiefly lactic acid, which temporarily overcome the buffer mechanisms. This means that the blood is actually more acid during the time one is breathless or panting after exertion. One breathes rapidly because these acids in the blood stimulate the respiratory centre of the medulla oblongata. This is a most delicate instrument, an extremely sensitive indicator of the amount of acid in the

blood. The respiratory centre responds by sending an increased number of impulses to the diaphragm and the chest muscles, so that they contract and relax more quickly until the excess of carbonic acid is exhaled, when there is a return to the normal rate of breathing. A rough measure of the alkali reserve can be obtained by gauging the time it takes after a standard exertion for the breathing to return to the normal comfortable state.

Another purpose of the extra breathing, besides removing carbon dioxide, is to supply extra oxygen needed to turn back into glycogen that portion of the lactic acid generated during the muscular contractions and still remaining in the muscles. For it has been shown that if the lactic acid, produced from glycogen during activity, is fed oxygen sufficiently quickly, a re-formation of glycogen occurs. The amount of oxygen so consumed is said to pay off the oxygen debt incurred during the exertion. But a certain amount of lactic acid escapes into the blood anyhow and disturbs the acid-alkali balance. At the same time relatively huge amounts of carbonic acid also escape into the blood.

It is by these that the respiratory centre in the medulla oblongata is affected. Answering the call, it makes the individual breathlessly eager to expel his bad air and breathlessly hungry for fresh oxygen. The respiratory centre may also act in the opposite direction—slowing respiration when there is an insufficient amount of carbonic acid in the blood, the condition of alkalosis. That is seen in mountain sickness when the first reaction of overbreathing, to make up for the relative deficiency of oxygen in the high mountain air, causes an excessive ventilation of the lungs with too great removal of carbon dioxide and consequent alkalosis. The same process may occur in inexperienced aviators or aeroplane passengers.

The Mobilization of Ammonia

Besides the buffers and breathing, the organism has at its disposal another mechanism for dealing with acid—the mobilization of ammonia. Ammonia is a useful household alkali, but a much more useful blood-tissue alkali. It is formed constantly in the liver and kidneys and all the muscles when the amino-acids, the chemical building-stones of proteins, are deaminated. The split-off amino radical forms ammonia.

Ordinarily the ammonia combines with carbon dioxide to form urea, the metabolite which was first synthesized by Wöhler, a contemporary of Liebig, who therewith founded the currently flourishing great science of synthetic organic chemistry.

Ammonia is not ordinarily produced as a reaction to an acidosis resulting from exertion or emotion which disturbs the bicarbonate-diphosphate ratio of the blood. Ammonia is mobilized when there is an increased formation of the abnormal fatty acids such as diacetic. These accumulate in diseases like diabetes, or in individuals readily developing ketosis. The ammonia content of his urine can be followed as a measure of an individual's susceptibility to the ketogenic diet, the diet deliberately used to decrease the irritability of the nervous system.

There is a principle deduced from the study of the metabolism of the sugars and fats which has developed an important practical application. This is to the effect that ' the fats burn in the fire of the sugars '. That is, the fats, containing less oxygen and more calories than the sugars, are not so easy to set on fire in the body as the sugars. And in fact, it takes a certain amount of burning sugar to bring about the complete combustion of fats. Otherwise acidosis results. Consequently, there is a necessity for mobilizing ammonia, to assist in maintaining the acid-base balance in the face of the oversupply of abnormal fatty acids of the diacetic-acid type. A limitation of the sugar ingested, a relative sugar starvation, may thus bring about an acidosis.

This has been taken advantage of in the construction of the so-called ketogenic diet, found useful in the treatment of certain pathologic conditions such as epilepsy. The ketogenic diet, a diet intended to provoke acidosis, is one containing an adequate amount of protein, a minimum of sugar, and a maximum of fat. Its important character uses consist in its employment for the control of certain explosive and impulsive behaviours, associated with an excessive wakefulness.

The ease with which acidosis can be produced and ammonia mobilized on a given low sugar, high fat diet can be used as an index of the individual's capacity to burn fat. When taken in conjunction with a simple test as to the ability of the individual to deal with ingested fat—his fat tolerance

curve—a quite definite indicator for diet constructing and control may be obtained. A high fat meal may be given the night before the determination of the blood fat is to be done. The next morning, while the patient is still in the fasting condition, a determination of the blood fat is done.

Fat is absorbed from the intestines along two paths. One is by way of the blood directly, being delivered to the liver. The other is by way of the intestinal lymph-carrying vessels, the lacteals, which all lead to the thoracic duct, and from it again into the blood. The existence of the lacteal-thoracic duct pathway is the best evidence of how carefully the organism guards the blood against being overloaded with fat.

In the blood the fat occurs as very finely suspended constantly moving particles which make it look milky. When the blood looks milky because of excessive fat content, *alimentary lipaemia* is present. Such milkiness is common after an ordinary meal containing much fat, but disappears in from eight to fourteen hours. If it is present in the morning fasting blood, we have definite reason for believing that a gross abnormality of fat metabolism is proved. Its absence, however, does not mean that a normal fat metabolism has been demonstrated.

In individuals with melancholia, it has been shown that the morning blood fat is too high. Naturally too high fat is found in those who are normally phlegmatic. A phlegmatic person, in fact, is one continuously slightly narcotized by the by-products of his fat metabolism. These are of the nature of the ketone substances, therefore constituting an acidosis (ketosis).

The fat content of normal human blood is about 2 per cent. It is all present either compounded with phosphorus, as the esters, grouped under the name of the 'lecithins', or combined with the waxy alcohols known as the 'cholesterols'. Milkiness of the blood due to difficulty in the assimilation of fat may be due either to an excess of these lecithin esters or an excess of cholesterol esters or both. Milkiness due to excess of cholesterol occurs much later than that due to excess of lecithin. Both these fatty substances, lecithin and cholesterol, as well as their esters, have to be measured in any consideration of the fat capacity of individuals.

The Excretion of Acid

One can imagine another method of disposal of acid by a machine, and that is the direct spewing out of it, immediate removal by excretory channels. And that is what happens in the animal body, by way of the kidneys and intestines, as well as the lungs. Just as acid carbonate is excreted by way of the lungs, acid phosphate is excreted by way of the kidneys into the urine. Of the phosphate of the blood in health, about 20 per cent is acid phosphate, and the other 80 per cent is alkaline phosphate. The acidity of the urine varies with the acid production of the body and the acid content of the blood, provided the kidneys are well-functioning. The total reserve alkali of the body may be measured as the sum of the urinary ammonia plus the titrable acidity, calculated as the amount of alkali necessary to bring the reaction of the urine back to the reaction of the blood.

Just as the kidney has the power to abstract acid from the blood, the intestines have the power to draw alkaline bases from the blood. The intestinal cells, affecting and affected by the reaction of their contents, assist in regulating the acidity of the blood. An increased acidity of their contents helps the absorption of calcium which is itself a neutralizer of acid. In alkalosis, the increased elimination of bases by way of the intestines facilitates the formation of soaps from fats, and thus interferes with the normal career of the fatty acids. Thus a triad of organs, lungs, kidneys, and intestines, as well as the buffers of the blood, act as lines of defence against the noxious effects of the constantly threatening acid, inorganic and organic.

Types of Acidosis

With these general principles of acid genesis, it becomes possible to apply their concepts to the varieties of acidotic, and particularly fatty-acidotic individuals, and their repercussions upon the nervous system and character. In the last twelve years the present writer has treated about fifteen hundred children suffering the effects of a grossly demonstrable acidosis of the ketosis type. They have all been subject to 'attacks' of metabolic crises, tending to rid them, temporarily at least, of accumulated acid and so tending to establish metabolic stability for the time being. These crises have

generally been of the nature of recurrent vomiting or there have been other manifestations of metabolic instability. In all cases, the metabolic instability, strain, or collapse has been found due to the interaction of the wrong diet and an individual whose chemical constitution is inadequately equipped to deal with the excess of fatty-acid food or foods. Therapy has consisted in the prescription of a modified diet, and also in the treatment of the chemical constitution with glandular extracts and other measures, to make it more capable of dealing with the difficult element of the diet.

A basic principle is the fact that fat is incompletely oxidized in the body when there is either a deficiency of glucose or difficulty in burning glucose, or when the blood is either too acid or too alkaline. A certain ratio must exist in the diet between the fatty-acid-forming (ketogenic) foods and the glucose-forming (antiketogenic) foods. This ratio, the ketogenic ratio, varies between 2 to 1 and 4 to 1, varying with the chemical constitution of the individual. This can be determined by the efficiency of the different endocrine glands, the thyroid, the pituitaries, the adrenals. In particular cases treatment logically takes both diet and the endocrine glands into consideration.

From the point of view of the acid-base balance and the ketogenic ratio, all foods may be classified as either acid producers (acidogenic), alkali producers (alkalogenic), and a small group of neutrals. Apart from individual constitution the acidifying effect of food varies with the season, with the amount of sunlight and variable humidity, with emotional stress, with exercise and lack of exercise. In winter, the diet tends to contain more meat and other acid producers, while in the summer, the greater intake of certain vegetables and fruits makes the metabolism more basic.

Of the fifteen hundred cases of acidosis in children mentioned, all other causes, gastric, intestinal, as well as local infection in the nose, throat, and teeth, have been excluded. A most detailed study of their metabolism, including the water, sugar, salt, and fat, as well as the basal metabolism, was made. As a result I have divided them into four varieties of chemical constitution, essentially dependent upon the dominance of their chemistry by excessive or deficient endocrine glandular function.

There is first the type which has a high blood sugar, between

and during attacks of metabolic upset, as well as a high basal metabolism when it can be measured, which may be called the hyperthyroid type, as it presents a number of the clinical signs of excessive function of the thyroid gland, such as moist, flushed skin, prominent eyes, rapidity of speech, movement and mental activity, as well as of heart. A second type has a low blood sugar, with a lowered basal metabolism, which may be called the subthyroid type, with a dry skin, rather sluggish movements, and a tendency to bookish inactivity. A third type, with a high blood sugar between attacks and a low blood sugar during the attack, may be named as the insular type (or diabetoid type), as these children remind one of the course of diabetes. In addition to having a history of diabetes in the ancestry, they present occasional traces of sugar in the urine and the occurrence of skin infections. These are helped by giving insulin. A fourth type, thin and sallow, easily fatigued, exhausted at the end of the day, developing attacks of recurrent vomiting during the night, are the children who may begin the day with a high or normal blood sugar, but have a definitely low blood sugar in the afternoon or toward evening, with a lowered basal metabolism, and acetone substances in the evening urine, or in the morning urine when taken before breakfast. This type may be described as the adrenal inadequate type, since, as I believe I have demonstrated, their symptoms, life history, and general character traits turn around the inconsistent daily function of their adrenals. This condition is dependent upon an inherent weakness of the adrenal glands probably dating from *the first few months of life.*

It is interesting to note in this connexion that the most recent work on the adrenal cortex points to a disturbance of the acid-base balance as the cause of the swift death which follows removal of the adrenal glands in animals. It is preceded by an accumulation of acid in the blood producing quickly a decrease of the alkaline reserves. This decrease is the direct cause of death. The acids involved appear to be mostly the phosphoric and sulphuric acids. The accumulation of acid and the subsequent fatality can be prevented or cured by the injection of extracts of the cortex of the adrenal glands. It looks as if the internal secretion of the adrenal cortex is the chief glandular regulator of the inorganic acidity of the bodymind.

Glucose administered by mouth, by rectum, under the skin or into a vein is good treatment for all of these cases. The use of bicarbonate should depend upon the determination of the presence of low alkaline reserve in the blood or urine. It should be remembered that suboxidation of fat occurs in alkalosis as well as in acidosis. If the presence of alkalosis is established, the administration of acid or ammonium chloride is indicated.

It has recently been shown by Koehler that the bad effects of acidosis as of alkalosis are due to suboxidation. This harmonizes with the conceptions stated by Berman and Kerley in 1920 and the name ' suboxidation syndrome ' then suggested by them. Acidosis is accompanied by loss of water and weight, dehydration, while alkalosis is accompanied by retention of water and increase of weight, hydration. The clinical symptoms of both may be alike : loss of appetite, nausea, vomiting, prostration, and drowsiness, and sometimes muscle pains.

All the clinical data at hand indicate the underlying metabolic and chemical phenomena in these children, who have recurrent attacks of acidosis when reacting to excitement, an infection, or an indiscretion of diet. These can be explained as due to a constitutional glandular imbalance of their personalities. They are the children whose fat-sugar mechanism is more easily strained or unbalanced than that of others whose metabolic reactions possess a larger margin of safety. The proper recognition of the fundamental disturbance of the ductless glands in this type of child is also most important for its future. For upon it depends the prevention of these metabolic and endocrine disturbances of adolescent and adult life which often present disabling difficulties of personality and character.

Of these types, the adrenal unstable and deficient are the most common and the easiest to recognize. Since the present writer described them in 1920 and reported the first studies ever made of their sugar metabolism, the results have been confirmed by Joseph, Gelston, Ross, and Cameron.

The Sugar-poor, Fat-defective, Nervous Child

To the most recent, the 1929 edition, of his book on *The Nervous Child*, Cameron, head of the children's department of Guy's Hospital, London, has added a chapter entitled ' The

Underlying Disturbances of Metabolism in the Nervous Child '. In this book, Cameron must be credited with having provided a detailed account of the complaints, symptoms, physique, and psychology of the so-called ' nervous ' child, really meaning the acidotic child. He described the type most interestingly—the instability of appearance and behaviour being most characteristic. He noted the curiously sudden passage of these children from a state of what passes for health to one of obvious illness—how they get pale around the mouth and dark about the eyes, their listless, shuffling walk and tendency to fall, their inability to concentrate at school, the passing but recurrent aches and pains in the muscles after exertion, and the proneness to development or exaggeration of nervous symptoms, such as tics, masturbation, squintings and stammerings, bed-wetting and tantrums, restless sleep, night terrors, and sleep-walking. Berman previously in his records of the clinical phenomena presented by these children observed this symptomatology, as also the curious morning nausea or dizziness, coated tongue, with the faint fruity odour of acetone to the breath.

Cameron compared these children with the sufferers from Addison's disease, the disease in which actual destruction of the adrenal glands is accompanied by attacks of nausea and vomiting, pallor, weakness, and complete loss of resistance to fatigue, a low blood pressure, and, back of the whole picture, a low blood sugar, with deficient adrenalin and intercortin. In ordinary, everyday exhaustion due to excessive exertion, intense emotional excitement, or persistent infection, a similar, though only acute and temporary, and self-repairing condition of depletion of the adrenal glands is physiological.

The adrenal glands assist in the mobilization of sugar in whose fire the fats burn. If they are slow or defective in driving sugar to the front, the fire of life becomes smoky and the fats deposit carbon like a badly burning candle. There develops the diminution of the alkaline reserves of the blood known as ' acidosis '. Acidosis predisposes to infection and infection in turn increases the acidosis, a vicious circle operating to produce the type of physique (muscular flaccidity), temperament (irritable excitability), and behaviour (laziness). These children, for instance, are constantly yawning, sighing, and taking deep breaths, not because they are bored or lazy or stupid, but in order to excrete some of

the excess acids accumulating in their blood because of smouldering acidosis.

The logical dietetic treatment for these adrenal-unstable children is an antiketogenic diet : that is, one high in sugar and low in fat. They have a high tolerance for sugar and a low tolerance for fat. These children have been much injured by contemporary propaganda in favour of a 'quart of milk a day' for health, based upon animal experiments and experiences with children of an entirely different type. A quart of milk contains about forty grammes of fat. Very often the fat capacity of an acidotic child is limited to a pint of milk a day, and frequently not even that. The best results are obtained by eliminating milk altogether from the diet. And these results are most striking, a complete change of character appearing within a few weeks, a change spotted, appreciated, and commented upon by the mother without any leading questions from the physician.

At the opposite pole are the children whose capacity to burn fat is good as is also their capacity to burn sugar, but who are much too excitable and who react excessively to the stimulants of the outside world. The excitability may attain the degree of reacting to stimulation with the attacks of convulsions classically known as epilepsy. These children also have a marked tendency to retain water. They are the superhydrated type, and there can be no doubt that the excitability of their brain cells is associated with a tendency to retain water. Too much water in the brain is the explanation of certain irritabilities and irascibilities of character which have hitherto had no physiological explanation. They can be treated by a diet low in water and sugar and high in fat. The individual thereby becomes dehydrated as well as sufficiently acidified for the acid to act as a natural sedative for the overstimulated brain.

CHAPTER X

PROTEINS CONFORMING TO INDIVIDUALITY

NO prettier example is extant of the effect of constitutional need and consequent unconscious bias in the special pleading of scientific questions than in the field of low protein as against high protein diets. Science is supposed to be immune to the prejudicial complexes of the vulgar in its cold and austere functioning. That is true, the history of science shows, only as long as no constitutional complex of the investigator is touched by the effect of his conclusions upon his personal life. Then all the evidence in favour of one side of a case becomes striking, while the points for the other side, willy-nilly, come to occupy a belittled place.

Proteins, compounds of the nitrogen-containing acids called the amino-acids, are the magical substances of life. Protoplasm, the basic substance of life, the physical basis of life, as Huxley called it, consists of proteins plus. The plus consists of water, salts, sugars, fats, vitamins, and a thousand and one other substances. No one ever thinks of the latter having the possibility of life, or as capable of developing the characteristics of life. But with proteins, the most complex molecules known in which are incorporated not only nitrogen, but also sulphur and phosphorus, is bound up the mystery of the creation of life, the origin and destiny of life.

Egg white is often mentioned as a typical example of a protein, a dead or non-living protein. It is capable, though, of becoming alive. Egg yolk contains the non-living sugars and fats, salts and vitamins. We know that the chicken germ, egg white reacting with egg yolk, makes the living protein, appearing as chicken breathing, chicken running, chicken eating, and so on. Similarly, all other proteins may become alive by reacting with living matter.

The essential constituents of proteins are the amino-acids,

which can be made artificially by the interaction of ammonia and fatty acids. Amino-acids are the fragments of proteins which appear when proteins have been blasted by the action of the digestive juices, by means of the digestive enzymes. Proteins form the structural material of all cells, such as those of the muscles and glands, and the amino-acids are the 'building-stones' of the proteins. There are twenty well-known amino-acids, and others have been described or remain to be discovered.

Protein metabolism is amino-acid metabolism—the chemical history of these amino-acids in the body. Not all proteins contain all of the necessary amino-acids. Gelatin, for instance, is a well-studied protein which is lacking in the amino-acids, tyrosine, tryptophane, and cystine. The indispensable amino-acids, those which are absolutely necessary for the maintenance of well-being and health, are these three and another, histidine. Few proteins contain all the amino-acids or even all the indispensable amino-acids. Proteins and the foods containing them may be graded as superior, good, or inferior, depending upon their content of the indispensable amino-acids.

Just as the letters of the alphabet are used to build words, so the body uses amino-acids to build proteins. Amino-acids may then be called the bricks of the proteins. As all the half-million words of the dictionary are constructed out of the twenty-six letters of the alphabet in different combinations, so are thousands of proteins, of animal or vegetable origin, composed of different sets of the known twenty amino-acids. But these amino-acids enter into their protein compounds not only qualitatively, but also quantitatively; that is, in variable proportions. This means that a whole series of variations in proteins are possible, depending upon the amount of a single amino-acid entering into their constitution.

During digestion in the intestines, the proteins are broken up into their constituent amino-acids, and after they are absorbed into the blood, new proteins are re-formed. New patterns are built out of them corresponding to the particular combinations of them which make muscle protein, nerve protein, skin protein, bone protein, and so on.

Now, imagine attempting to write English sentences without five or six of the most important frequently recurring letters. It would be impossible to construct certain words.

People who attempt to nourish themselves with incomplete proteins—that is, with proteins not containing all of the indispensable amino-acids—are in the same position.

Foods, therefore, may be arranged in the order of the biological value of their proteins, which is their capacity to supply the amino-acids which cannot be synthesized by the body. To become protein conscious in diet is to become amino-acid conscious. And there are only a few foods which are protein perfect. That is, there are few foods which contain proteins composed of all the necessary amino-acids. That is why it is impossible to live on a single food and why mixtures and varieties of meals are desirable (besides the reasons of palate and taste). Milk, for example, is by no means a perfect food, because it is definitely deficient in certain amino-acids, as well as in minerals.

We owe this rather illuminating analogy between the amino-acids of proteins and the letters of the alphabet to McCollum and Simmonds, who have put the matter as follows :

> Kossel, Fischer, and Osborne made it clear that there existed very pronounced differences in the composition of the proteins from different sources. The proteins were prepared in a state of relative purity, were digested in the laboratory by means of acids, and were analysed by the methods of Fischer and of Kossel. Certain of the eighteen digestion products, the amino-acids, were determined quantitatively so far as the methods would permit. Although the technique was never perfected so as to give results approximately quantitative, except in the case of less than a third of the amino-acids known, it was shown in the case of these few that there were great variations in the proportions among them in the mixtures obtained from proteins from different sources. Thus, the proteins of the muscle tissues of several species of animals yield between 12 and 14 per cent of glutamic acid, one of the products of hydrolysis obtained from proteins. This amino-acid is present in the two principal proteins of the wheat kernel to the extent of about 40 per cent. These two proteins together make about 85 per cent of the total protein of the wheat kernel. Other equally great differences were shown to exist in the composition of proteins of common foods, and those of the tissue proteins of animals.
>
> The problem which the animal meets in its protein nutrition may be illustrated by comparing the digestion products of the protein molecule to the letters of the alphabet. The proteins of the food and of the tissues which are unlike each other may be

regarded as made up of the same letters arranged in different orders and present in different proportions. In growth, the food proteins which the animal takes are taken apart into simple compounds, the amino-acids, which are absorbed and put together in a new order, and new proportions, to form the tissue proteins.

If the muscle tissue of an animal be compared to a block of printer's type so arranged as to print the rhyme beginning ' Jack Spratt could eat no fat, and his wife could eat no lean ', let the proteins of which the muscle consists be represented by the letters of which the word consists. If now the animal should take food proteins which correspond to a block of type which would print the jingle beginning, ' Peter Piper picked a peck of pickled peppers ', it is easy to understand that when the proteins of the food are resolved into their constituent letters, and an effort is made to form the body proteins of the new and different type from the letters supplied by the food, the transformation cannot be made. In ' Jack Spratt could eat no fat and his wife could eat no lean ', we need four of the letter ' t ', but the food proteins contain but one. The first line of the Jack Spratt rhyme, which represents the muscle proteins, contains but one ' p ', whereas the food proteins expressed by the Peter Piper rhyme yield nine in the first line. The first line of the Jack Spratt rhyme contains the letters ' j ' and ' n ', whereas the Peter Piper rhyme contains none, so that even with the entire stanza—

Peter Piper picked a peck of pickled peppers,
If Peter Piper picked a peck of pickled peppers,
Where's the peck of pickled peppers
That Peter Piper picked ?—

it is not possible to produce even the first line of the Jack Spratt rhyme, and in order that growth might become possible, it would be necessary to take proteins of another character which would supply the missing letters.

Zein, of corn, is entirely lacking in three of the amino-acids or digestion products which are obtainable from most tissue proteins. In accordance with what we should expect on theoretical grounds, this protein is incapable of supporting growth, or of maintaining an animal in body weight, when taken as the sole source of amino-acids. This illustration shows how we may have superior, good, or inferior food, proteins for the formation of body proteins in growth.

The number of protein compounds possible can be gathered from the following table envisaging the possible combinations of amino-acids, ranging from 2 to 20 :

Number of Amino-Acids	*Number of Possible Proteins*
2	2
3	6
4	24
5	120
6	720
7	5,040
8	40,320
9	362,880
10	3,628,800
11	39,916,800
12	479,001,600
13	6,227,620,800
14	87,178,291,200
15	1,307,674,368,000
16	20,922,789,888,000
17	355,687,428,096,000
18	6,402,373,705,728,000
19	121,645,100,408,832,000
20	2,432,902,008,176,640,000

Amino-Acid Wear and Tear

Now, whereas sugars and fats have primarily a fuel or heating, energy-producing value, the amino-acids function primarily as reinforcements for cells that are worn out and die, such as blood cells: or for cells or cell material that is lost, such as skin, hair, and nails; or for secretions, internal and external, such as are being continually manufactured and consumed in metabolism. A red cell lives about thirty days, so that every month fresh, newly made red cells are recruited into the blood from the bone marrow. The same is true of the white cells. Skin, hair, nails, all amino-acid compounds, kidney and intestinal cells, mucous and bile, all are being constantly lost and must be replaced. To take care of this nitrogen, amino-acid, protein waste or loss, a certain minimum of the essential amino-acids, or the superior proteins containing them, must be ingested daily.

This internal or endogenous metabolism of protein amino-acids must go on at all costs. The flow of nitrogenous matter in and out of the body is a flux which cannot be interrupted for a moment, day or night. New living matter has to be constructed to maintain the delicate balance of the blood cells, the skin cells, and the cells of the internal organs. If not enough food containing the proper amino-acids is pro-

vided, the body feeds upon itself to provide them, destroying certain less necessary cells to make the more necessary ones. The unique amino-acids, therefore, play a unique role in life.

Chemical analysis of the blood and urine provides the best indicators of the rate and kind of nitrogenous metabolism accompanying the flux of matter in the cells of the body. Urine has long been studied for clues to the history of proteins in the cells. It contains materials out of which all possible use has, so to speak, been squeezed out. Out of these fragments of what was once living tissue or took part in the activities of living tissue, the biochemist, in the role of a Sherlock Holmes, deduces past events and reconstructs a picture of what has happened in the immediate past. Foremost among these end products of amino-acid metabolism in blood and urine is the substance urea.

Urea, Indicator of the Nitrogen Balance

Urea is the substance which, because it was first made artificially about a century ago by the German chemist, Wöhler, co-worker of Liebig, has become the historic starting-point of the intimate research into the chemistry of the cell, characteristic of modern biology and medicine. When Liebig first heard of its synthesis, he refused to believe it. So imbued was he, too, with the dogmas of the ancient vitalism which preached that no human mind could ever really solve the chemical mysteries of the living and penetrate its secrets so definitely as to be able to imitate its methods of manufacture of its chemicals.

Thus it shares with Lavoisier's measurements of oxygen consumption and carbon-dioxide production the honour of establishing the absurdity of a 'No Poaching' sign for the efforts of the human bodymind to investigate and understand itself without stint or limit. Nowadays a large number of compounds can be listed as the synthetic evidence of man's increasing power to understand and control the process which he calls his life. And, in fact, no substance found in the living body is regarded as properly understood until it has been made and remade in the laboratory, with resulting insight into its chemical constitution.

Urea is a white crystalline water-soluble substance of a neutral reaction which may be regarded as the outcome of an interaction of the ammonia and carbon dioxide constantly

being produced in cells. It occurs in relatively large quantities in the urine, as about 80 per cent of food nitrogen is excreted as urea. On the ordinary mixed diet it amounts to a respectable percentage of the total urinary solids. It varies with the amount of protein eaten. When the amount of protein is large, the urea output is considerable, and when the amount of urea is small, it may be inferred that the protein intake has been little. A balance is established between income and outgo of nitrogen at various levels, the actual point of balance being known as 'nitrogen equilibrium'. The parallelism, of course, is true only as long as the kidneys are functioning normally. The quantity of urea in a twenty-four-hour specimen of urine may, therefore, be used as a measure of the amount of protein that has been broken down during the day.

Even when no protein at all is being consumed—as in fasting or starvation, or on a diet of pure fats and starches—a certain amount of urea continues to be excreted. The amount, though less than on the ordinary mixed diet, is a definite quantity just the same. The urea of protein deprivation or starvation must be derived from the proteins of the living cells. A *negative nitrogen balance,* as the condition is described when the nitrogen of the urea is debited without a sufficiently balancing credit of food nitrogen, cannot be maintained indefinitely, and death results.

On the other side of the scale of possibilities is the establishment of a *positive nitrogen, amino-acid balance.* That is, more protein is taken than is excreted. Such is normal for growing children or the growing tissues recuperating after the wasting effect of an illness like pneumonia or typhoid fever. Under ordinary conditions, the body adapts itself to increasing protein intake by refusing to store it, removing it, or, at any rate, the nitrogen part of it, as urea. Increasing the protein of food is not immediately followed by the establishment of a nitrogen equilibrium. It may take several days, sometimes as much as a week, depending upon the ratio of increase. But in a healthy, vigorous, active subject, nitrogen equilibrium, equivalence of the incoming and outgoing nitrogen, is attained in about that time.

The Two Functions of Proteins

It is an interesting and surprising fact that nitrogen equilibrium cannot be produced by feeding an amount of protein

equal to that which is lost during a period of no food or starvation. It would seem that if protein food acts to repair the daily loss of the cells, an amount equal to that lost would be the logical answer to the question : How much protein should one eat ? Actually it has been found impossible to achieve nitrogen equilibrium, let alone a maximum of health and general effectiveness, on such a basis. If the fasting equivalent of nitrogen is fed, a negative balance occurs. And it is only upon a certain level or plane of protein intake that an equilibrium is established.

Nor can the irreducible minimum of nitrogen be determined by feeding a 100-per-cent carbohydrate diet giving all the calories needed, but no nitrogen. Upon such a diet, the excreted nitrogen does reach the lowest attainable level, lower than that of starvation, which means that sugar is to a certain extent a 'sparer' of the protein. But if the food protein is added to such a carbohydrate diet in an amount equivalent to the nitrogen loss, equilibrium will not be attained. If an all-fat diet is fed, the minimal nitrogen loss will double that of an all-sugar diet. A diet composed of half sugar and half fat produces a nitrogen loss that is the equivalent of one consisting wholly of carbohydrates.

All these experimentally demonstrated principles tend to show that besides its *replacement* function, food nitrogen has another, a *second*, and perhaps equally important, function, and that is, its *stimulating* function. When meat is fed, there is a rise in metabolism quite out of proportion to that which occurs after a meal of an equivalent amount of sugar or fat as regards calories. The same is true of cheese and chicken, as well as beef, indeed, of a great variety of fish, flesh, fowl, and vegetable proteins. This effect has become known as the 'specific dynamic effect' of protein.

The stimulating effect of proteins has been analysed by Lusk and his pupils, who have proved it to be due to the action of certain of the amino-acids liberated during digestion. The most potent of these stimulating amino-acids are glycin, alanin, and phenyl-alanin. They, it will be noted, are quite different from the amino-acids needed for replacement purposes—cystine, histidine, tyrosine, and tryptophane. In considering constitutional differences in protein requirement, it will be important to differentiate the effects of these two types of amino-acids—the replacement group and the stimulating group.

The Stimulating Effect of Protein

The stimulating or specific dynamic action of protein is often ignored in calculating the fuel needs of the body in terms of calories. Ordinarily, when the amount of calories of heat energy to be taken as fat or sugar is being calculated, only two factors are considered. One is the basal metabolism, or the 'overhead' in energy expenditure—the energy consumed when the body is at rest as a whole and the activities of its parts have been reduced to a minimum, the stomach being empty, the blood chemistry being constant, the body temperature at its lowest, the heart and the breathing at their slowest, growth and maintenance of cells being least. The other factor usually considered is bodily activity or muscular work.

On this basis, a clerk, pursuing a sedentary daily occupation, needs less food than a longshoreman who works hard, using every muscle of his body. Overhead activity has thus become the formula for calculating the calories in diets. The overhead or basal metabolism can be calculated in relation to the age, size, and shape of the person as derivable from a comparison of his height and weight. Charts are available which give one the 'normal' basal metabolism or 'overhead' output of energy per hour per pound of weight. Other tables have been made showing the calories of different activities as follows (Rose and Henry):

Activity	*Approximate Number of Calories needed per hour for each Activity by a Person weighing on the average 155 lbs.*
Awake, lying still	75
Sitting, at rest	100
Writing (sitting down)	105
Standing, relaxed	105
Reading aloud	105
Sewing (handwork)	110
Standing at attention	115
Knitting	115
Dressing and undressing	120
Singing	120
Typewriting (50 words a minute)	125
Tailoring	135
Typewriting rapidly	145

Activity	*Approximate Number of Calories needed per hour for each Activity by a Person weighing on the average 155 lbs.*
Light ironing (5-lb. iron)	145
Dishwashing, small articles	145
Sewing at machine	150
Bookbinding (woman)	160
Bookbinding (man)	170
Sweeping bare floor (38 strokes a minute)	170
'Light exercise'	170
Light housework, cooking for 2 persons, sweeping rugs, bedmaking	180
Shoemaking	190
Walking slowly (3·75 miles per hour)	200
Housework, moderate; cooking for 10–12 persons, ironing 6–7-lb. iron, scrubbing by hand, sweeping carpets	225
Metal-working	240
Carpentry, light	240
Mail carrier	250
Housework, hard; cooking for large groups, ironing with large heavy irons, scrubbing, heavy implements	250–300
Carpentry, heavy work	270
Walking (6 miles per hour)	300
Stone-working	400
Farmer	400
Sawing	475
Running (5·3 miles per hour)	570
Very severe work, as that of lumberman, stevedore, excavators	600 or more

Calorie Needs of the Nursing Mother

Add to the diet of the nursing mother:

90 calories for each pound the baby weighs until 3 months old
85 ,, ,, ,, ,, ,, ,, ,, ,, 6 ,, ,,
80 ,, ,, ,, ,, ,, ,, ,, ,, 8 ,, ,,
70 ,, ,, ,, ,, ,, ,, ,, ,, thereafter

Calorie Needs of Old People

For persons from 60–70 years of age reduce 10 per cent of calories
,, ,, ,, 70–80 ,, ,, ,, ,, 20 ,, ,, ,, ,,
,, ,, after 80 ,, ,, ,, ,, 30 ,, ,, ,, ,,

Calorie Needs of Babies and Children

Baby:	First 3 months	50	calories a pound a day
	Second 3 months	50–45	,, ,, ,, ,, ,,
	Third 3 months	45–40	,, ,, ,, ,, ,,
	Fourth 3 months	45–40	,, ,, ,, ,, ,,
Child:	Second year	45–40	,, ,, ,, ,, ,,
	Third, fourth and fifth years	40–35	,, ,, ,, ,, ,,
	Sixth and seventh years	40–30	,, ,, ,, ,, ,,
	Eighth and ninth years	40–30	,, ,, ,, ,, ,,
	Tenth to fourteenth years	40–30	,, ,, ,, ,, ,,
	Fourteenth to seventeenth years	30–22	,, ,, ,, ,, ,,
	Eighteenth to twenty-fifth years	25–18	,, ,, ,, ,, ,,

Method of using the preceding tables to estimate the approximate number of calories which an adult may spend in a day: Make a typical day's programme as follows:

Sleeping	8 hours @ 65 calories an hour	520
Awake, lying still	1 hour @ 75 calories an hour	75
Dressing and undressing	1 hour @ 120 calories an hour	120
Eating meals (this would compare with knitting or typewriting)	1½ hours @ 120 calories an hour	180
Going to and from business (walking slowly)	1½ hours @ 200 calories an hour	300
Work in office (typewriting rapidly)	7 hours @ 145 calories an hour	1,015
Reading aloud	2 hours @ 105 calories an hour	210
'Light exercise'	½ hour @ 170 calories an hour	85
Writing letters and reading	1½ hours @ 105 calories an hour	157
	Total calories for day	2,662

The above is calculated, as said, for a person weighing 155 pounds. One weighing less than 155 pounds would need correspondingly less, and one who weighed more would need correspondingly more. The proportion can be worked out as a matter of simple ratios. However, the condition of the endocrine glands, such as the thyroid, also determines the waste of energy accompanying activity. In certain cases it becomes important to take that factor into consideration.

Protein the Activity Catalyst

It is seen that the expenditure of an activity, like writing while sitting down, the activity of a clerk, adds about forty calories to the overhead ; while a farmer needs ten times as much as an addition to his overhead and a stevedore even more. In the case of the clerk, the overhead seems to constitute the greatest proportion of the energy consumed, and in the case of the farmer or stevedore, it would appear to be the activity expenditure.

Yet the physician does encounter writers who remain thin, sometimes cadaverously thin, on the calculated calorie intake, and lumbermen who remain fat even though they work hard and do not exceed the food quotas of their fellows. When a study is made of such individuals, they may be found healthy as regards their organs and well-balanced as regards the functioning of most of their glands of internal secretion. But they differ in one very important respect—the stimulating effect of protein upon the metabolism in the case of the thin writer is very large and in the case of the fat stevedore is quite small. The more protein the clerk eats, the more stimulated his body is to burn its sugar and fat, while the other, the stevedore, lacking any marked stimulating effect of protein upon his metabolism, tends to store his extra protein as fat and carbohydrates.

This also explains other differences, character differences, psychic differences, between them. When it is understood that the stimulating or specific dynamic reaction of protein, occurring at least three times in twenty-four hours, tends to raise the metabolism by 20 to 40 per cent—that is, by one-fifth to two-fifths of itself—it becomes easy to understand why, in calculating a diet, or in studying the effects of a diet, it becomes necessary to take it into consideration. The formula for calorie determination is thus, not simply overhead plus activity, but overhead plus food stimulation plus activity.

We have good reason to believe that the stimulating effect of the stimulating amino-acids (the effect of any protein is a summation of its constituent amino-acids) is proportional to the content in the liver and in the muscles of the hormones of the thyroid and pituitary glands. The maximum effect occurs during the second hour after the ingestion of the stimulating proteins. Mann has shown that in animals with-

out a liver the specific dynamic action of glycin and alanin is not obtained. Nor can the specific dynamic action of protein be obtained in animals without a thyroid. This can be correlated with the fact that animals without a thyroid cannot develop a fever when they are infected or poisoned. The influence of the pituitary has been studied by Plaut in human beings and by Foster and Smith in animals.

Plaut determined the basal metabolism in cases of pituitary-gland disease showing obesity with atrophy of the sexual organs. The basal metabolism was determined, and then a standard breakfast of minced meat, bread, butter, and coffee was given. The specific dynamic effect amounted to about 10 or 11 per cent, while in normal controls it was 20 to 30 per cent. After administering injections of extracts of the anterior lobe of the pituitary, the prepituitary gland, the specific dynamic action was increased 17 per cent, making a total of 27 per cent, which is within the average range. Plaut also found that in people who are the so-called constitutionally thin—those who remain thin no matter what they eat—have increases ranging from 48 to 63 per cent above their basal metabolism, a range 100 to 200 per cent above normal.

Foster and Smith found in their animals that removal of the pituitary caused a drop in basal metabolism of 25 per cent. The administration of glycin resulted in no increase, that is, in no specific dynamic action, as it does in the unoperated control animals. The metabolic rate is restored to the normal by the daily injection of prepituitary extracts, but not of post-pituitary extracts. But extracts of both pituitaries must be administered simultaneously if the normal specific dynamic action of glycin is to be obtained in such animals.

It follows that the protein content of the diet must be related to the specific replacement needs of the individual, determinable by tests, and to his stimulation capacity as affected by the functioning of his thyroid and pituitary glands.

How Much Protein do We Need?

But protein is important not only as a stimulant of metabolism—it functions also as a determiner of the level of the overhead in energy expenditure. It has been established that one of the effects of fasting is a lowering of basal metabolism. This lowering of the basal metabolism is due to an insufficiency of protein, for if the proper proteins are supplied, the basal

metabolism is restored to normal. If only fats, sugars, salts, water, and vitamins are given, and little or no protein, the basal metabolism remains at the same lowered level. And if an inadequate amount of protein is given, the metabolism will rise, but not to the normal level.

A sufficient amount of adequate protein—that is, protein containing the essential amino-acids—is necessary for the maintenance of a normal basal metabolism. And, indeed, the feeding of a high protein diet over a period of time tends to raise the level of the basal metabolism to a new and higher plane. In other words, the stimulating effect of protein registers itself in time upon the rate of consumption of oxygen even at rest. However, the normal basal metabolism provides at least one clue to the fundamental question: How much protein shall any particular individual eat or be permitted to eat?

What is a minimum and maximum of protein intake, as well as an optimum, are the problems to be solved in studying the relation of amino-acid metabolism to personal characteristics. The minimum protein intake can be defined as that amount which is necessary to maintain a normal basal metabolism and a normal temperature. For a subnormal basal metabolism is accompanied by a subnormal temperature.

To distinguish the subnormal basal metabolism and subnormal temperature of inadequate protein in the diet from the subnormalities due to glandular deficiencies, a study of the chemistry of the urine is of value.

All chemical compounds of the urine are also found in the blood under normal conditions. Their amounts and relationships change under different protein intakes of the food. The fact can be utilized to establish a protein minimum for any individual.

The Creatinine Coefficient

We need a means of measuring the rate at which we die as of that at which we live. For we are continually dying as we are living—that is the essence of the doctrine of metabolism. This means is furnished by the substance occurring in the urine known as 'creatinine'. Creatinine may be made chemically from the methylated amino-acid, creatin, which is an abundant chemical constituent of muscle. As a result of the fundamental investigations of Folin, Shaffer, and others, the

extremely significant fact was established that the amount of creatinine in the urine is wonderfully constant for any individual, being independent of the food protein, but directly proportional to the replacement protein. Thus, as was first demonstrated by Folin, the significance of the amount of the creatinine output is essentially different from that of the urea. The urea rises and falls almost in direct proportion to the quantity of protein in the food. The creatinine output, on the other hand, remains almost the same, whether the protein content of the diet be high or low. On a low protein diet, the urea may fall to one-sixth of what it was on a high protein diet, but the creatinine remains almost unchanged from hour to hour as well as from day to day.

The daily output of creatinine, although so constant in a given individual, varies in different individuals with the degrees of muscular development. Obese persons who have flabby atonic muscles have a low creatinine output, while lean people who are well developed muscularly have a high creatinine output. But, in general, the creatinine output is proportional to the body weight.

Upon that basis, Shaffer proposed the term 'creatinine coefficient' to describe the number of milligrams of creatinine eliminated per kilogram of weight in twenty-four hours. He regarded this creatinine coefficient as an index of muscular development. In thirty-seven normal men the creatinine coefficient was between 8 and 11. In entire agreement with this view, Tracy and Clark found the creatinine coefficient of twenty-six normal women students in a professional school to average 5·8. In two athletic women, with muscles extraordinarily developed by gymnastic exercise, the creatinine coefficients were 9 and 9·8, or the same as in men. This looks as though the creatinine metabolism is an index of the quantity of active protoplasm of muscle tissue. Also it is the proteins of muscle cells that are called upon to sacrifice themselves when there is an insufficient amount of protein in the diet. Muscular work on a so-called normal diet does not increase the creatinine output, except during partial or complete starvation when there is an actual destruction of muscle tissue.

In protein deficiency, the total nitrogen of the urine decreases, while the nitrogen specifically determinable as the creatinine nitrogen increases. The creatinine nitrogen reflects

the breakdown of muscular protoplasm when it is called upon to supply extra protein to supplement the insufficient quantity in the food. Thus a normal ratio of the total nitrogen of the urine to the creatinine nitrogen can be established, a constant when enough protein is present in the diet. This ratio is 28. The creatinine content of the urine is directly proportional to the protein used in metabolism, that is derived from the cells as distinguished from the metabolizing protein derived from food. We may define the protein minimum of any given individual as that amount containing the adequate amino-acids which will maintain a normal basal metabolism and temperature and a constant creatinine output, the total nitrogen output being about twenty-eight times as great as the creatinine nitrogen. This protein minimum is no fixed amount, but varies from individual to individual.

High Protein versus Low Protein Diets

So much for the determination of the protein minimum for any given individual. But is it good for one to subsist, or to attempt to subsist, upon the protein minimum or just above the protein minimum ? And is there a protein maximum, above which it is harmful or dangerous to go for a period of time ? And may there not be an optimum between minimum and maximum, specific for each individual, upon which he functions best, superlatively adapted to his physiology and psychology ?

Curiously enough, the problem of a high protein diet versus a low protein diet as the optimum or ideal has become connected in the history of the subject with the question of meat-eating and the problem of a *high meat versus low meat diet*, or carnivorism versus vegetarianism. There is no genuinely rational reason for this association, except perhaps that natural high protein-eaters are meat-eaters, while natural low protein-eaters tend to be vegetarians. By natural high protein-eaters—proteinophiles—I mean those who are so constructed metabolically that they need a great deal of protein and have a capacity to handle as much as they need. Natural low protein-eaters—proteinophobes—have a much lowered capacity to metabolize amino-acids, do not need as much, and consequently do not crave them as much. But a high protein diet can be fairly easily constructed without meat from the practical standpoint, as well as the theoretical—one, that is,

which can be purchased in the ordinary market without much trouble.

Meat is turning out to have other advantages as a food besides its high protein content, to be pitted against its disadvantages as an acid-former and its content in the uric-acid-forming purins. It has been shown quite recently, in experiments comparing various foods with liver for their content of blood-forming agents in anaemia, particularly pernicious anaemia, that meat contains all the structural elements out of which haemoglobin (unique pigment of the red cells) is manufactured. But most interestingly it has been demonstrated that meat is a stimulus to the secretion of the blood-forming hormones, as well as of the digestive juices of the stomach.

When meat interacts with the gastric juice, a substance is produced, sometimes referred to as the 'Castle hormone', having the capacity to stimulate the bone marrow to manufacture and mobilize millions of new red-blood cells. It has become important in the treatment of pernicious anaemia, hitherto considered a malignant and inevitably fatal disease the progress of which could be stopped and reversed by no known remedy. First liver and now stomach have been proved to be dependable therapy for the disease, transforming it from a major invalidism ending in death into a relatively mild and controllable affliction. No other food can compare with meat in its capacity to generate the 'Castle hormone'.

'Ventriculin' is the name that has been suggested to designate the blood-forming internal secretion of the stomach. Tripe has been raised to a sudden importance as the source of a therapeutic substance. But it is out of its interaction with meat and other foods that the hormone active in the making of blood is released.

Individuality and the Protein Controversy

In 1901, Professor Russell Chittenden, one of the most outstanding American biochemists, who was educated in the views of the Munich School of Voit, as chief of the department of physiological chemistry in Sheffield Scientific School, Yale University, in a lecture on 'The Value of Meat as Food', expressed an orthodox position of that time in favour of the high protein diet. Chittenden, not religious in his attitude, but scientific, changed to prove to himself the better diet:

Understanding now that the main function of protein foods is to supply the nitrogen needed by the body, we may ask: What advantages do meats possess as a source of this nitrogen? In answer, we may reply, that they represent a concentrated form of protein food, their nitrogen is readily available, they are easily digestible, they have an agreeable flavour, they add variety to the diet, they contain extractives which have an exhilarating and stimulating effect, they satisfy the pangs of hunger more completely and for a longer period than the vegetable proteins.

The suprarenal is one of those glands that until recently have been considered as devoid of any very marked physiological action, but, as we now know, there is formed in the medulla of that gland something which has a striking physiological effect upon the muscular system generally, and especially upon that of the heart and arteries. Its action is to increase the tone of all muscular tissue, and this result is produced mainly, if not entirely, by direct action. This action can be demonstrated in a negative way, by simply removing the suprarenal capsules from an animal, when there is produced extreme weakness of the heart and of the muscular system generally, and great want of tone in the vascular system. Hence, it would appear that at least one of the functions of the suprarenal capsules is to produce a material which is added in some way to blood, and the effect of which is to assist, by its direct action upon the various kinds of muscular tissue, in maintaining that amount of atonic contraction which appears to be essential to the physiological activity of the tissue. It must also be remembered that there are other so-called ductless glands in the animal body, such as the thyroid, which undoubtedly also manufacture certain products which find their way ultimately into the blood, and traces of these may likewise be present probably in the muscular tissue, and hence become components of the 'meat'.

These statements may be taken as an illustration of a principle which I believe worthy of some consideration, viz., that, in satisfying the needs of the body for proteid foods with meats, we derive certain advantages other than those associated simply with the proteid matter itself. Various extractives, active principles, etc., all endowed with more or less physiological properties, are likewise ingested as a part of the meat, and add their effects perhaps to aid in keeping up the tone and utility of the organism. . . .

The hard-working labourer is the man who above all others needs the full complement of proteid food, and he is adding to his own strength and prosperity, as well as of his children's, when he is able to provide his family with a reasonable amount of animal proteid. . . .

In conclusion, allow me to say that, in my judgment, meats occupy a somewhat peculiar place in our category of dietetic articles. A close examination of the dietetic custom of civilized

people shows that two distinct objects are ever kept clearly in view, viz., the satisfying of the grosser needs of the body, the needs of general nutrition, and satisfying the needs of the higher functions of the central nervous system. Now meats plainly share with vegetables, fruits, dairy products, etc., the ability to minister to the former wants of the body, but in addition they have certain stimulating properties which distinguish them from the grosser vegetable foods. In this respect they might almost be classed, perhaps, with such articles as tea, coffee, etc., in their power of ministering to the wants of the brain and nerves. As Sir William Roberts well says: 'The struggle for existence, or rather, for a higher and better existence among civilized men, is almost exclusively a brain-struggle, and these brain-foods, as they have been not inappropriately termed, must be regarded as a very important part of the equipment for that struggle. . . . If we compare as best we may, with our limited information, the general characteristics of the high-fed and the low-fed classes and races, there is, I think, to be perceived a broad distinction between them. In regard to bodily strength and longevity, the difference is inconsiderable, but, in regard to mental qualities, the distinction is marked. The high-fed classes and races display on the whole a richer vitality, more momentum and individuality of character, and a greater brain power, than their low-fed brethren, and they constitute the soil or breeding ground out of which eminent men chiefly arise.'

He concluded as follows:

So with mankind the nature and quality of the nutriment, aside from its containing the one proportion of the several requisite elements, exert a specific influence upon the character of the mind and body, and meats may be fairly placed in the front rank of foods as giving important aid toward that higher physical and mental development which belongs to the civilization of the nineteenth century.[1]

How Chittenden switched from the Voit Standard

This was at the beginning of the present century. But a few years later, Chittenden had a complete change of heart and attitude, what was, indeed, a conversion to the *contrary doctrine of a low protein, meat-poor diet.* The immediate cause of the conversion was the propaganda of Horace Fletcher, originator of Fletcherizing, and author of the *A B Z of Our Own Nutrition*, a book which caused quite a stir when it came out at that time. It made Fletcher famous as the

[1] Quoted from Hindhede, *Protein and Nutrition.*

promulgator of a doctrine of Eating only When Hungry and Swallowing only the Well-Chewed to Live Long. He claimed that every one could develop a special reflex by which all food not masticated would be automatically regurgitated. The origin of Fletcher's efforts was a constitutional need, as he said himself in his book:

About ten years ago, at the critical age of forty-four, the writer was fast becoming a physical wreck in the midst of a business, club, and social tempest. Although he was trained as an athlete in his youth, and had lived an active and most agreeable life, he had contracted a degree of physical disorder that made him ineligible as an insurance risk. This unexpected disability, with such unmistakable warning, was so much a shock to his hopes of life that it led to his making a strong personal effort to save himself. The study was taken up in a systematic manner, an account of which is too long to relate here; but the eager self-reformer soon learned that his troubles came from too much of many things; among them, too much food and too much needless worry; and realizing the danger ahead, he sought a way to cure himself of his disabilities by the help of an economic food supply as did Luigi Cornaro; but what is even more important, he found a way to enjoy the smaller quantity of food much more than any plethoric luxury can give, and arrived at the method by a route that showed a means of conserving a healthy economy and an increased pleasure of eating, at the same time, in quite a simple and scientific manner, that anyone may learn and practise without any ascetic deprivation whatever. Cornaro buried the real clue to his economic and pleasurable success with his body, owing to his vague generality of description of his method. The writer is determined not to make the same mistake, and thereby bury his key to a happy and easy life.

Chittenden, who himself was not well, became interested in Fletcher's methods. As a result of his interest a series of experiments were carried out by him upon Fletcher. At about the same time he experimented along similar lines upon himself. Concerning Fletcher he wrote:

In the autumn of 1902 and in the early part of 1903, Mr. Fletcher spent several months with the writer, thereby giving an opportunity for studying his habits of life. For a period of thirteen days in January he was under constant observation in the writer's laboratory, when it was found that the average daily amount of protein metabolized was 41·25 grs., his body weight (75 kgs.) remaining practically constant. Later, a more thorough series of observations were made, involving a careful analysis of

the daily diet, together with the analysis of the excreta. For a period of six days the daily diet averaged 44·9 grs. of protein, 38 grs. fat, 253 grs. of carbohydrate, the total fuel value amounting to only 1,606 large calories per day. The daily intake of nitrogen averaged 7·19 grs., while the daily output through the urine was 6·3 grs. and in the faeces ·6 gr.; that is, a daily intake of 7·19 grs. nitrogen, and this on a diet containing less than half the proteid required by the Voit standard, and having only half the fuel value of the Voit diet. Further, it was found, by careful and thorough tests made at the Yale gymnasium, that Mr. Fletcher, in spite of this comparatively low ration, was in prime physical condition. In the words of Dr. Anderson, the director of the gymnasium: 'The case is unusual, and I am surprised that Mr. Fletcher can do the work of trained athletes and not give marked evidences of overexertion. . . . Mr. Fletcher performs this work with greater ease and with fewer noticeable bad results than any man of his age and condition I have ever worked with. It is not our purpose here to discuss how far these results are due to insalivation, or the more thorough mastication of food. The main point for us is that we have here a striking illustration of the establishment of nitrogen equilibrium on a low protein diet, and great physiological economy as shown by the low fuel value of the food consumed, coupled with remarkable physical strength and endurance.

Chittenden carried out a series of experiments on himself following Fletcher's suggestions. After the experiments he wrote:

Accustomed to eating daily an amount of food approximately equal to the so-called dietary standards, recognizing that the habits of a lifetime should not be too suddenly changed, a gradual reduction was made in the amount of protein or albuminous food taken each day. In the writer's case, this resulted in the course of a month or two in the complete abolition of breakfast, except for a small cup of coffee. A light lunch was taken at 1.30 p.m., followed by a heavier dinner at 6.30 p.m. Occasionally, however, the heartier meal was taken at noontime, as the appetite suggested. It should be added that the total intake of food was gradually diminished, as well as the protein constituents. There was no change, however, to a vegetable diet, but a simple introduction of physiological economy. Still, there was, and is now, a distinct tendency toward the exclusion of meat in some measure, the appetite not calling for this form of food in the same degree as formerly. At first, this change to a smaller amount of food daily was attended with some discomfort, but this soon passed away, and the writer's interest in the subject was augmented by the discovery that he was unquestionably in improved physical

condition. A rheumatic trouble in the knee joint, which had persisted for a year and a half, and which only partially responded to the treatment, entirely disappeared (and has never since recurred). Minor trouble, such as 'sick-headaches' and bilious attacks, no longer appeared periodically as before. There was a greater appreciation of such food as was eaten; a keener appetite and a more acute taste seemed to be developed, with a more thorough liking for simple foods. By June, 1903, the body weight had fallen to 58 kilos.

During the summer the same simple diet was persisted in—a small cup of coffee for breakfast, a fairly substantial dinner at midday, and a light supper at night. Two months were spent in Maine at an inland fishing resort, and during a part of this time a guide was dispensed with and the boat rowed by the writer frequently six to ten miles in the forenoon, sometimes against head winds (without breakfast), and with much greater freedom from fatigue and muscular soreness than in previous years on a fuller dietary.

Health, strength, mental and physical vigour, have been maintained unimpaired, and there is a growing conviction that in many ways there is a distinct improvement in both the physical and mental condition. Greater freedom from fatigue, greater aptitude for work, greater freedom from minor ailments, have gradually become associated in the writer's mind with this lowered protein metabolism and general condition of physiological economy. The writer, however, is fully alive to the necessity of caution in the acceptance of one's feelings as a measure of physical or mental condition, but he has been keenly watchful for any and every sign or symptom during the course of these experiments, and is now strongly of the opinion that there is much good to be gained in the adoption of dietetic habits that accord more closely with the true physiological needs of the body. If a man of 57 kgs. body weight can maintain a condition of equilibrium with continuance of health, strength, and vigour (to say nothing of possible improvement), with a daily consumption of, say, 40 grs. of protein food, and sufficient non-nitrogenous food to yield 2,000 calories, why should he load up his system each day with three times this amount of protein food, with enough fats and carbohydrates to yield 3,000 plus calories?

Finally, the writer, in summing up his own experience, is inclined to say, that while he entered upon this experiment simply with a view to studying this question from a purely scientific and physiological standpoint, he has become so deeply impressed with the great gain to the body by this practice of physiological economy, and his system has become so accustomed to the new level of nutrition, that there is no desire to return to the more liberal dietetic habits of former years.

In putting the last question, Chittenden was attacking the orthodox position concerning the amount of protein an active man should eat in a day, a standard established by Voit, the successor of Liebig as the leader of the study of metabolism in the latter half of the nineteenth century. Now, Voit became the leader of the *high protein diet* propaganda. He was an entirely different constitutional type from Chittenden. His physical appearance, as well as his aggressive attitude toward life and stubborn polemic conflicts with his opponents, all suggest the carnivore or natural meat-eater, while Chittenden's physique and psychique, as well as his ailments and illnesses, suggest the herbivore or natural vegetarian.

Their constitutional differences are easily deducible from their photographs. Voit, the German, who worked at the University of Munich, was short, squat, plump, short-necked, well-fed—the aggressive extrovert. He was the hyperadrenal, hyperpituitary type, and could well live on the high protein diet he advocated. Whereas Chittenden is the long, lanky Yankee, asthenic introvert, he appears the thin hyperthyroid, adrenal deficient, and pituitary unstable. No wonder he thrived best on a daily intake of 45 to 55 grammes of protein, whereas he developed headaches, rheumatism, etc., when he tried to take as much as Voit could take and recommended for others.

This is a perfect example of how protein intake should conform to the *individual*. And the difficulty of following a scientist who generalizes his own personal standards for the rest of mankind.

Upon the basis of his experiments with dogs, as well as statistical analysis of actual diets of the German people, Voit had arrived at the conclusion that the quantity of protein necessary for maintenance is no less than two and a half times as much as that consumed during starvation. He bolstered this conclusion with fifteen experiments carried out upon two men. Then, as a result of collating various observations upon how much humans and in particular Germans eat, he constructed the textbook standard of the average self-maintaining diet for a moderately active person as about one hundred and twenty grammes of protein. This turned out to be about three times as much protein as Chittenden found sufficed for himself.

Voit claimed, too, that races which used less protein (meat

and dairy products)—that is, chiefly vegetarian races—were historically less active, vigorous, and progressive. Voit's standard was based upon the assumption that an individual's diet is the result of choice as dictated by the requirements of the survival of the fittest. To put it in another way, Voit taught that his standard was universal because it was the outcome of experiments carried out by the human race over hundreds of generations.

Most recent experiments have shown that an insufficient protein intake causes not only a subnormal basal metabolism, but also a lowering of the protein content of the blood. Not enough protein in the blood causes a retention of water in the tissues, an overhydration, with disastrous consequences for the healthy chemistry of the tissues, upsetting various balances of the salts, cholesterols, and lecithans. Chittenden might have checked the effects of protein malnutrition upon himself by following the daily changes in the protein content of his blood.

Because these facts were unknown at that time, Chittenden was not acquainted with that possibility. But he proceeded to check the results of his experiment upon himself by carrying out with Mendel a series of similar experiments with five university teachers, eight student athletes, and thirteen soldiers over a period of nine months. In all of them good health and mental vigour persisted on his low protein diet. According to muscular tests, the strength and endurance of the athletes was increased by the Chittenden diet. The same was true of the soldiers. The teachers declared that their mental powers were greatly benefited.

Inspired by Chittenden's results, Irving Fisher conducted a similar series of experiments upon students at New Haven, Conn. He reported that upon a low protein diet with lessened calories over a period of two months they regularly augmented their endurance, which means they decreased their fatigability, in a number of physical tests. In 1918, Benedict published the conclusions of a similar series of experiments, agreeing with Chittenden and Fisher. But as soon as the experiments were over, most of those who submitted to the experiment returned to their previous habits of much higher protein consumption.

A Danish Protagonist for Low Protein

The most strenuous advocate of a low protein meat-poor diet has been M. Hindhede, director of the Hindhede Labora-

tory for Nutrition, established for him and maintained by the Danish Government in Copenhagen. Hindhede was born in 1862, his father being a prosperous farmer in West Jutland, Denmark, who was able to send his son to Copenhagen University to get a medical education. He passed his final examination in 1888, with the highest honours bestowed by the university since 1847. While at school he carried out some experiments upon himself perforce in the matter of diet. He himself has described his early experience most interestingly.

More than twenty years ago, I learned from the late Professor Panum, of Copenhagen, that 4·2 oz. (120 grs.) was the smallest amount of protein which would suffice an adult, vigorous man. It would not do to depend on the vegetable kingdom alone for this amount, because vegetable protein is too difficult of digestion, and too large quantities of vegetable foodstuffs, relatively poor in protein, would have to be consumed in order to obtain the required amount of protein. For this reason the necessary 4·2 oz. should be drawn, to a certain extent, in equal measure from both the vegetables and animal kingdom ; and thus it was that our attention was directed to the supreme importance of meat.

This doctrine took me by surprise. I was born and reared in simple circumstances in West Jutland ; and during the first sixteen years of my life, my fare had consisted of milk-porridge and bean-soup for breakfast ; thick slices of bread, sparsely buttered, with very thin slices of meat, or with none at all for lunch. Dinner began with porridge, milk-cabbage and pea-soup, followed by potatoes and bacon, fish at times, meat very rarely, and then only in very small slices, while there was no limit to the quantity of potatoes provided. In the afternoon we had a meal of bread and butter, as in the forenoon ; and in the evening ' sour porridge '—groats cooked with large barley corns in buttermilk—an excellent dish, and relished by most people once they have become accustomed to it. This very monotonous fare contained, therefore, only a negligible quantity of that form of food which my teacher held to be the most important—meat. I explained to my astonished father that all this rye bread, as well as all those potatoes, meant pot bellies, flabby muscles, and consequently deficient energy. The Irish and Japanese were cited as deterrent examples. It was only later that I became aware that the majority of West Jutlanders were, in truth, anything but pot-bellied ; that their energy was actually prodigious (working from fourteen to sixteen hours per day). The Irish, who are notoriously potato-eaters, are very virile, and in America, where they are often to be seen serving as policemen, their physical appearance

is very imposing. The Japanese, also well known as being mostly vegetarians, have proved themselves to possess wonderful powers of endurance allied with keen mental qualities.

To return to myself, I lived as a medical student in Copenhagen, and prepared my own breakfast and supper. As this fare contained little protein and no meat at all, I made up for it by dining in cheap restaurants. In such places, fortunately, one could choose the various courses at will. To make doubly sure, I would order a double portion of the main course, and I looked with the superior scorn of a scientist upon my poor, ignorant fellow-citizens, who were stuffing themselves with thin soups. Strange to relate, instead of becoming muscular, as I expected, I grew weaker and weaker. My cousin, who lodged with me, and who followed me through thick and thin, was the first to cry halt. To my horror, he began to eat soups ; I held out for some time, but gave in at last. The demon of doubt began to torment me ; and when I had finished with Copenhagen, and had settled down in West Jutland with the intention of reforming existing conditions there, those connected with nutrition among others, there was hardly anything left of my physiological wisdom but a great perplexity. But no one can be a reformer who is himself in doubt ; and thus reformation was delayed. Then came vegetarianism, into the study of which I threw myself with eager zeal. But in vegetarianism I found too many contentions, either unproved or impossible of proof, and the catch-phrase 'Back to Nature' I conceived to be untenable. I could not bring myself to recognize that, considered by itself, it is more natural to eat baked bread than cooked meat. Our teeth, to be sure, indicate that we are fruit-eaters ; but a strict fruit diet is unpractical for an inhabitant of the north, banished from the paradise of the south.

Finally our kitchen-middens (domestic refuse-heaps of primitive peoples) do not point to any particular marked vegetarianism in our ancestors. We must go right back to the apes, and even these, our far-away progenitors, are reputed to have been eaters of young birds, to say nothing of eggs. As already remarked, I could not agree with vegetarianism in the theory, but for all that, there might be some virtue in it. I gave it a practical test. For one month I restricted myself to pure vegetarian diet ; and what is more, selected only those vegetarian foods as poor in protein as I could think of. I lived chiefly on butter, bread, potatoes, sugar, and fruit—especially strawberries. I wanted to find out how long I could live on such a limited quantity of protein. Of course, it was not my intention to prolong the regimen until death threatened ; I merely wished to keep to it until I felt myself becoming really weak. To make more certain, I applied myself, meanwhile, to vigorous physical exercise, such as garden-

ing, cycling, etc. But, strange to say, no infirmity evinced itself; to the contrary, I experienced excellent health. I never had that feeling of tension and sluggishness which usually follows the consumption of a good beefsteak. With the end of the strawberry season, I relinquished my assumed part. But these experiments, which were afterwards repeated with many variations, had convinced me of one fact, and that was that the little story of the 4·2 oz. of protein is nothing but sheer fable; since which time—now some seventeen years ago—very little meat is eaten in our house—most days we have none at all; and I am always exhorting my children to eat plenty of porridge, bread, and potatoes, and very sparingly of meat, eggs, etc. We adults, as well as children, eat a great quantity of potatoes, not only at dinner, but also at supper. In the evening, if there be no potato salad or potatoes served in some other way on the table, we are sure to hear a loud cry from the children present, 'Are there no potatoes?' One of the reasons why the potato has earned such an evil name must certainly be that there are so many bad potatoes on the market. Watery or unsound potatoes make a truly dreadful dish; but good, sound potatoes form, in my opinion, a palatable and easily digestible food which, for no reason at all, has come to be despised.

He put up his shingle as a country doctor in his native Jutland immediately after graduating, although solicited by his tutors to remain at the university and set up in practice in Copenhagen. One of the first practical effects of his experiments and propaganda among the farmers of his practice was the introduction of a low protein diet for their cattle. They were so satisfied and trumpeted his fame to such an extent that a committee of them petitioned the Danish Government to assist him in his researches by furnishing him with a laboratory and the means to give his time completely to the investigation of the protein problem. In January, 1911, he was inaugurated director of the first government-aided laboratory in Europe for the study of human nutrition. In this laboratory he carried out carefully detailed experiments upon human beings, with scientific studies of the chemistry of the urine.

During the Great War, Hindhede's great chance came. He was made food controller of Denmark and the feeding of the whole nation was put into his hands. He rationed his people in accordance with his ideas, and for those four years the four millions of Denmark lived upon the low pro-

tein diet of little meat, but much bran and potatoes. As a result there was a sharp drop in the Danish death-rate, with something of an upward rebound at the end of the food-rationing period when the war was over and the people returned to the fleshpots of Egypt.

Since 1912, Hindhede has published twenty-five reports comparing the effect of his diet upon health and efficiency with that of the high protein consumers. One of them, for instance, shows the advantages of the low protein diet as practised by the 'Back to Nature' colony of Eden, a group near Berlin. Again and again he has emphasized the superiority of the high fat, low protein diet of the Danish farmers as contrasted with the high protein, low fat of the neighbouring Finlanders. During a visit he made to the United States in 1928, he defended the ascetic protein diet tooth and nail, when he again pointed out the striking differences in favour of the Danish diet as compared with that of certain of the American States. Altogether Hindhede has made himself the most prominent and vociferous protagonist of the low protein type of feeding.

Holck's Auto-Experiment

A most recent carefully conducted and controlled experiment in Fletcherizing with a low protein diet is that of Harold Holck, an experiment carried out over a period of five years upon himself. The actual time devoted to the diet was seventy-five weeks of the five years, the rest being control periods of variable diet used for comparison. Every article of food was weighed to the nearest gramme on a spring scale kept scientifically corrected. Water intake was equally carefully measured. Eating time, sleeping time, the amount of urine, and the body weight were exactly recorded, and even the defecation rate.

Holck's protein intake was about a gramme per kilogram of body weight. He was somewhat obese at the beginning of the experiment, and lost about thirty pounds, which brought him close to his supposed normal weight. As regards eating time, this was, during the experiment, roughly double that of control periods, and calculated as twenty-three minutes per thousand calories. Records of the actual eating time were obtained by means of a stop-watch, but he himself writes: 'No calculations of calories, proteins, carbohydrates, and fats

consumed were made until the experiment had been concluded for fear our eating should be influenced by these data.'

He came to the following conclusions:

1. That a low protein diet, with Fletcherizing, of an adequate number of calories decreased basal metabolism, muscular endurance, and typewriting accuracy.

2. That it had no significant effect upon blood pressure, pulse, oral temperature, sleeping time, mental multiplication, and typewriting speed.

3. That it induced improvement in efficiency of solving chess problems which persisted into the final control period. There was improvement with queen, bishop, king, pawn as first moves, whereas no significant change occurred with knight and rook. Analysis of his results indicated that 'during Fletcherizing we worked more uniformly or showed lesser tendency to get stuck'.

4. That intellectual improvement occurred in association with a lowering of the basal metabolism is one of the interesting results of this experiment. It seems to confirm the assertions of Fletcher, Chittenden, Fisher, and Hindhede as regards the effect of a low protein diet upon intelligent work, but contradicts them in nearly all other respects. The effect upon basal metabolism agrees with what was found in the case of Fletcher himself by the great German investigator, Zuntz. Fletcher was then sixty-three years old and had just lived for three months on a diet of only potatoes and butter.

McCay and the Bengalis

On the other side, in the protein controversy, the critical attack of McCay, who practised among the Bengalis in India, is prominent. He emphasized the differences in growth and vitality of the poorer Bengalis who consumed the lowest quantity of protein and the more well-to-do who eat much more of it. One of his interesting and definite findings was the fact that on a high calorie, low protein diet Bengali students failed to gain in their chest measurements in three years, while Anglo-Indian and Eurasian students who lived on fewer calories, but on a third more of protein, gained an average of an inch in their chest girth.

Several studies have been made of the relation of high protein diets to kidney damage. For it has been claimed

that the kidneys are overworked by a high protein diet, and that the overwork ultimately causes disease of the kidneys. Some of the work is vitiated again because the constitutional food habits of the animal concerned is not taken into consideration. This is certainly true of the work on rabbits of Newburgh and his collaborators. They found marked kidney injury in rabbits as a result of a meat diet. But rabbits are not ordinarily meat-eaters.

McCollum fed rats much of a combination of beefsteak and casein, and liver and casein, and obtained severe kidney injury. But Osborne, Mendel, Park, and Darrow found no kidney injury with high casein diets. Most recent investigations indicate that the *kind* of protein and the *duration* of its feeding make a great deal of difference. In summarizing, McCollum and Simmonds, who have carried on experiments with all sorts of food mixtures in a number of different species, watching them through many generations, conclude as follows:

> The extensive nutrition studies on animals seem to place in a new light the older literature relating to human nutrition. There is no instance in our experience where a diet satisfactory in all other respects, but supplying just sufficient protein of good quality to support growth at approximately the maximum rate to the full adult size, has been found to promote as satisfactory nutrition over the entire span of adult life as would the same diet containing a more liberal supply of the protein factor. It has been frequently assumed by students of nutrition that after growth has been attained the nutritive needs of the body for protein can safely be met by a dietary in which the protein content is lower than is essential for optimum growth. Of the numerous experimental data from the work of McCollum and Simmonds, none support this view. They all point to the conclusion that when the life history of the individual is considered, a generous protein ingestion or one allowing a fair margin of safety over the lowest percentage which just suffices to induce maximal growth in the young, serves to maintain vigour for the longest possible period.

It is one of the principal theses of the present volume that it is dangerous and irrational to draw general conclusions concerning food requirements for everybody from experiments carried out upon themselves by single individuals, or even small groups of individuals, when no data are provided concerning their glandular make-up. We should know what

their constitutional ability to handle different foods is, and then only generalize for the type. In this whole matter of the protein optimum and minimum, it would appear obvious that certain races live upon a low protein diet because they were built to live upon a low protein diet, since their capacity for metabolizing protein was low. While others, being so constructed that they need and can deal with a large protein intake, are at their best when on a high protein plane of metabolism. In short, constitutional differences in the ability to utilize protein—that is, to store or burn the amino-acids completely as well as to get the benefits of their specific stimulating effects for the bodymind—are fundamentals which cannot be ignored in studying the action of the protein quota upon a given individual's personality.

The Eskimo Diet

That different races have different diets, and that they differ particularly in their protein intake, is a fact which has a definite bearing on the problem of recognizing individual differences in food requirements and their relation to character and personality. That the staple cereal amino-acids of the Mongolian diet have been mostly derived from rice, the Amerindian from corn, and the Caucasian from wheat has undoubtedly contributed to the differences between races. Of all the races studied, the Eskimos present the type of diet most interesting from the standpoint of its protein content.

In 1913, August and Marie Kroh, Danish experts in nutrition, published their remarkable results of a study of the metabolism of Eskimos. They established a scientific station in Greenland and equipped it with the suitable apparatus after overcoming the most stubborn obstacles. They found that the Greenlanders completely reversed the formula of the Europeans in the nature of their food. Instead of containing about five hundred grammes of carbohydrate, it contained only fifty grammes. And instead of a hundred or a hundred and fifty grammes of protein, it held two hundred and eighty grammes, while the amount of fat was about one hundred and thirty-five grammes. The protein was all animal-derived, being meat and fish, the favourite foods being everything they get out of the seal, the walrus, the whale, and the reindeer.

The Eskimos are the human carnivores of the world, for

they may exist for long intervals on purely animal food. Seaweeds, whortle-berries, half-digested plants found in the stomachs of reindeer, may be their only source of supply of 'greens'. Dr. Stefansson has estimated that about half of 1 per cent would be about the proportion of vegetables to the rest of their diet. On this high protein, low carbohydrate diet, the Eskimos present almost none of the characteristics supposed to be associated with a high meat diet. They are peaceful and unaggressive. They have produced no geniuses and have made no capital contribution of any kind to the intellect of the human race.

But it is significant in this connexion that Kroh found that there was a delay in the utilization of the protein and very little specific dynamic action of it. This is quite a contrast to how Europeans react to a high protein diet, with a quick utilization of the protein and a marked stimulation of their metabolism by it. It explains the difference between the effect of a high protein diet in the Eskimos and in the Europeans, and shows how the reaction of the endocrine glands to a given diet is the important determinant of what food does to character.

An attempt has been made to conclude from these facts about the Eskimos that European man could thrive upon a similar high protein, low carbohydrate, that is, all-meat diet. And the experiment has been actually carried out on the Arctic explorer, Dr. Vilhjalmur Stefansson, and his companion. In his book on his experiences in the Far North, the explorer pointed out that out of eleven and a half years spent there, he had lived for nine years on meat and water, and without salt for six years out of the nine. During this time he says he remained in good health, being sick only once with an attack of typhoid fever complicated by pneumonia and pleurisy, which he treated with a diet of frozen raw fish and later large meals of caribou.

It was asserted that Stefansson and his companion continued in excellent condition when they were kept on an all-meat diet in New York. An analysis of the contents of their meals revealed, though, that they derived most of the calories of their food from fat, which makes it distinctly misleading to speak of it as an all-meat, implying 100 per cent meat, diet. It was a diet containing more protein (meat protein) and less starch and sugar than the average New York

diet. That is all that can be said about it. And an inspection of the health protocols of the explorers by no means bears out the conclusion of 'excellent health'.

Even if they had done as remarkably well as they claimed on a really 100 per cent meat diet, the only valid conclusion would be that they, like their Arctic spiritual brothers, the Eskimos, were built to consume and handle without self-injury large quantities of meat. Of Scandinavian stock, Stefansson's general constitutional make-up would cause him to resemble the Eskimo constitution more than most other people. And so he would be acclimatized to their food by heredity. But it by no means follows that the French, the Italians, the Spaniards, the South Russians or English, the Irish or Americans, would thrive upon it. As a matter of fact, most of them would soon be made ill by it.

Acidosis explains why any number of individuals would be injured by the meat diet of Stefansson and his companion. Even they increased their output of acid tremendously. And there can be no doubt that this increase of urinary acid is due to the effect upon metabolism of the high content of acid-forming material in the meat and fat. In other words, an acidosis was produced, compensated, to be sure, but a strain on the organs, nevertheless. Such a diet continued over a period of time in susceptible individuals would result in injury, disease, or even a lethal outcome, as shown by the experiences of Merz and Mawson, who had to live on dog meat alone in the Antarctic regions. As for the effects of it upon the brain and nervous system and all the aspects of mental functioning, they also would be bound to be deleterious in individuals whose endocrine glands would not be adequate for the task of dealing with the extra stress upon metabolism following the ingestion of large quantities of fat and meat associated with little or no intake of minerals and carbohydrates.

The secret of individual differences in reaction to various levels of protein intake, high or low, is definitely a matter of the glandular formula. The drift of metabolism is determined by whatever ductless gland is functioning least efficiently. Consequently, it becomes imperative to know just how the ductless glands are functioning before assigning the protein limit of a patient.

Just as individuals vary in their sugar tolerance and in their

fat tolerance, they also vary in their protein tolerance. Differences in the capacity to deal with proteins are evident even in the first year of life. Good nutrition and bad nutrition during childhood may depend upon whether the proteins are forced or limited. The growth during puberty may reflect the quality and quantity of proteins supplied to the changing organism. At every point in the life curve the protein quota is subject to mutations of constitution.

The Role of the Ductless Glands

Fundamentally, the clue to individual differences in the need for protein, correlated with the ability to metabolize protein, has turned out to be differences in the capacity and efficiency of the endocrine glands to deal with the amino-acids. A vast amount of research needs to be done in this field. But enough practical information is available as regards at least three glands to make possible judgement in individual cases concerning the amount of protein to be prescribed in a diet and in particular the amount of meat.

At least two glands, the adrenals and the parathyroids, are involved in the handling of special fractions of the complex protein molecules of meat, the incomplete metabolism of which may poison the bodymind.

When the adrenal glands are removed, death is inevitable in a few days. In the meantime, the animal becomes very sick, exhibiting all the symptoms of a poisoning, the burden of which the kidneys become unable to bear. Of all foods, meat is by far the most toxic, and death can be much hastened by the administration of it to the sick creature.

The poisoning is of the acid type, due to the accumulation of acid products of metabolism in the blood, of which meat is one of the most productive. At the same time a marked aversion to fat, another source of acids, develops. Hypodermic injections of extracts of the cortex of the adrenal glands will relieve these symptoms of acid poisoning and enable the animal to survive indefinitely as long as the injections are continued. A practical corollary of these observations is that a low protein, meatless diet is of value in people presenting the signs of adrenal gland deficiency. Low adrenal types of individuals are the natural vegetarians.

As regards the parathyroid glands, similar observations have been made. An animal with the parathyroid glands

removed goes into the convulsions of tetany in twenty-four to forty-eight hours. These convulsions are repeated until the animal dies. The convulsions are preceded by a loss of lime through the kidneys and intestines and a lowering of the calcium content of the blood. Upon the injection of calcium salts or of a parathyroid extract which increases the calcium content of the blood, the convulsions cease and the animal walks about as if apparently well. If the injections are not repeated, the blood calcium falls again and convulsions again shake the animal.

In human beings similar conditions occur. Now, the frequency of occurrence of the convulsions, as well as their severity, may be varied by the protein and especially the meat content of the diet. A high meat diet will lead to explosive outbreaks of the convulsions with death ensuing, while a meatless diet may keep the animal free of convulsions, giving it a chance to recuperate and perhaps to survive. The exact mechanism of the action of meat in these parathyroid conditions—whether due to the elaboration of poisons in the spastic intestine or to the accumulation of some poisonous by-product acting in the presence of an insufficient amount of lime in the blood—remains to be determined.

Those who have a constitutional or an acquired parathyroid insufficiency should be put upon a meatless diet. Calcium metabolism is involved in all the important relations of the parathyroid glands to character and behaviour. Certain neurotics of the lime-poor type have discovered for themselves that they do best on a meatless diet. Sometimes they make a virtue of their constitutional necessity by giving moralistic reasons for it.

Two other endocrine glands which are concerned in the disposal of the amino-acids are the pituitary and the thyroid. Both of these glands have an influence upon the specific dynamic action of proteins. When the thyroid gland is removed, there is a loss of protein in the blood, which loss is recovered when thyroid or protein is fed. Thyroxin stimulates the destruction of protein, and protein in turn stimulates the production, or, at any rate, the mobilization, of thyroxin. That is, individuals with hyperthyroidism or exophthalmic goitre are much more uncomfortable and unco-ordinated after a protein meal than after a carbohydrate meal. A high protein, low sugar diet is indicated in thyroid deficiency,

a low protein, high carbohydrate diet is indicated for the hyperthyroid.

The influence of the pituitary upon nitrogen metabolism has been worked out only most recently. In 1921, Evans and Long reported that they had manufactured giant female rats, twice the size of the average, by the injection of extracts of the prepituitary gland. They were able to accomplish the feat because rats retain the ability to grow throughout life, as their bony epiphyses never completely close.

Following the work of Evans and Long, Teel and his collaborators were able to produce the condition of acromegaly, a condition of overgrowth of all the organs including the bones, in dogs, by means of injections of a purified extract of the prepituitary containing the growth hormone. They studied the blood chemistry before and after the injections. They found that the active growth promoting extract caused a decrease of the non-protein nitrogen of the blood, which includes the urea and amino-acids. In other words, nitrogen disappeared from the blood, to supply building stones for the new tissue being made, as exhibited in gain of weight and general overgrowth of the animal.

This conclusion was confirmed by the urine analysis, which showed marked retention of nitrogen and a complete disappearance of phosphorus. When there is retention of both nitrogen and phosphorus, one may be sure it is due to their segregation for the manufacture of new cells. At the same time there was a definite diminution of the rate of basal metabolism. The growth hormone of the prepituitary evidently plays an important role in amino-acid metabolism.

The Appraisal of Protein Tolerance

It follows from these considerations that protein tolerance, the limit of an individual's capacity to metabolize and assimilate protein, is decided by the efficiency of the parathyroid and adrenal, thyroid and pituitary glands. A deficiency of the parathyroid and adrenal glands indicates a low protein diet, as does a hyperactivity of the thyroid. In the case of the latter, and in proportion to the increase in the metabolism, the excessively necessary calories should be supplied in the form of carbohydrates and fat, easily assimilable and not so readily fermentable. A deficient pituitary indicates a low protein diet. Conversely, adequate or superior

functioning of the parathyroid, adrenal, and pituitary glands call for adequate or even high protein diet.

Of course, in individual deficiencies or superiorities of any one of these glands, the other dietetic indications must be met. For example, in parathyroid deficiency there is a complete upset of the intermediate protein metabolism, with an increase of the ammonia amino-acid and polypeptid content of the urine, corresponding to a proportional decrease of urea. Also there occur toxic amines of the guanidin group, which can be related to a disturbance of the muscle metabolism. In adrenal deficiency, other types of acids, of the sulphuric-acid group particularly, increase. In the hyperthyroid, the creatin content of the urine is greatly augmented.

In view of these considerations, it becomes evident :

1. That the routine prescription of a standard amount of protein per kilogram of individual is a mistake.

2. The protein intake should be individualized upon the basis of the needs and capacities of the constitution.

3. The best clue to the constitutional protein requirements is the endocrine formula which predicts the essential characteristics of metabolism. The endocrine formula may be determined by a series of tests of the different ductless glands. High protein or low protein or specific protein feedings can be based upon it.

4. Certain character reactions can be controlled by varying the protein intake of the diet.

CHAPTER XI

THE ROLE OF THE PURINS

Gout and Genius

GOUT has been called the disease of genius. Certainly many distinguished men have suffered from it. Havelock Ellis, analysing the *Dictionary of National Biography*, found that gout occurs at least five times as often among British men of genius as in the common run of the population. Among those afflicted were Milton, Harvey, Newton, Gibbon, Fielding, Samuel Johnson, Congreve, Wesley, and Charles Darwin.

This high incidence of gout in genius is by no means limited to the British. Martin Luther had it. The Jesuit Father Balde published a book on gout in 1661, in which he labelled it 'Dominus Morborum et Morbus Dominorum' (the leader of diseases and the disease of leaders). And Sydenham, one of the greatest clinical observers in the history of medicine, who had gout himself for thirty-four years, wrote in his treatise on the disease:

> It may be some consolation to those sufferers from the disease who, like myself and others, are only modestly endowed with fortune and intellectual gifts, to know that kings, princes, generals, admirals, philosophers, and many more of like eminence have suffered from the same complaint, and ultimately died of it. In a word, gout, unlike any other disease, kills more rich men than poor, more wise than simple.

Two hundred years later, Sir Spencer Wells wrote:

> Those who are known to be subject to gout are among the most distinguished for an ancestry rendered illustrious by high thoughts and noble deeds, for their own keen intelligence, for the assistance that they have afforded to improvement in arts, science, and agriculture, and for the manner in which they have led the spirit of the age. . . . I have never met with a real case of gout, in

other classes of the community, in a person not remarkable for mental activity, unless the tendency to gout was clearly inherited.

Gout also is a disease of families of great ability. The Bacons and the Pitts were gouty families. Piero di Medici, who founded the powerful Medici family, had gout so badly that finally he was able to use only his tongue, being so completely disabled by the disease, according to Cabanes, the great French student of the relation of medicine to history. Piero's son, Lorenzo the Magnificent, also suffered from gout, as did his son, Lorenzo II, the father of Catherine di Medici, who married into the French royal family. It was recorded that she had a peculiar craving for artichokes which have a reputation for being anti-gouty for some reason. Henry IV was attacked by both gout and migraine. Louis XIV, who said, '*L'état, c'est moi*', had gout all his life, as is documented in the *Journal of the King's Health.* The disease manifested itself in all his Bourbon descendants, Louis XV, XVI, XVIII, and so on. Other famous French families afflicted with gout were the Richelieus, the Rohans, and the La Rochefoucaulds.

Gout is thus undoubtedly a disease of disturbance of metabolism connected with the manifestations of personality and character, which present themselves as outstanding intellectual ability, emotional instability, general eccentricity, and productive capacity. It is a disease which has long been recognized to be associated with what are spoken of as 'indiscretions of diet'. It behoves us to consider, therefore, some of its relations to food and the ductless glands. In the pursuit of its phenomena, it may be possible to attain a clue and additional insight into that most tantalizing and attractive of problems: the nature of the metabolism of leadership and genius.

The Symptoms of Gout

Gout may be defined as a constitutional disease which manifests itself in an acute or chronic inflammation of certain joints, most characteristically of the feet and hands, but it may appear in any joint. The gouty attack is due to the deposition of crystals of the sodium salt of uric acid known as sodium biurate. That is why uric acid has come to be the dominating problem in medical considerations of the disease. But besides the gouty paroxysm, there may be dis-

turbances of all the other organs, from the skin inward, which exhibit the symptoms of *irregular* gout.

Preliminary symptoms frequently warn of the coming of the gouty paroxysm. These may consist of manifestations on the part of the digestive system: disturbances of the appetite, abdominal cramps and gas, frequent urination, or a sense of disturbance in the liver region. With these or without them may occur symptoms referable to the nervous system: such as excessive irritability and sensations of itching, numbness, or coldness in the extremities. These symptoms may be present for many days. Then one evening the individual goes to bed, to be awakened about two or three o'clock in the morning with a feeling of great pain in one of the small joints, classically in the ball of the great toe, but it may begin in the heel, or the instep, or even in some part of the hand, particularly the thumb.

The joint affected assumes a deep red colour, is swollen, and extremely tender. The pain is always worse at night during the duration of the attack, which may be a week or ten days. One foot or hand may be the seat of the attack, then the other or both. These attacks tend to recur in the same joints. But after a time other joints become involved until all of them are implicated in the disease. The attacks are then not so painful, but the internal organs begin to show signs of degeneration. The kidneys, the heart, and the large arteries, as well as the stomach and liver, show signs of derangement. The relation between gout and gravel in the urine is one of the well-known associations of the disease.

At the same time chalky deposits form in and about the joints. These, peculiar to gout, and known as 'tophi', make their first appearance as a semi-fluid solution of sodium biurate, which solidifies and interferes with the free movement of the joint. Such a tophus consists of a calcium salt of uric acid, the calcium replacing the sodium. These lime urates may also form in the skin and tendons, and most characteristically in the cartilages of the ear, so that the diagnosis may be made by a mere inspection of the individual's aural appendages.

Gout and Uric Acid

How and why uric acid should be deposited and crystallized in the joints of the gouty has been and still is one of the

incompletely solved mysteries of biochemistry. It was the English physician Garrod who showed that gout is characterized by the fact that there is an increased amount of uric acid in the blood. This increase may be at least 100 per cent and it may be several hundred per cent. But there is no increased uric-acid output observable in the urine, except during the acute attacks. Such acute attacks are terminated by a sharp rise in the elimination of uric acid by the kidneys, a veritable flooding or washing-out of it.

It is as if something were interfering with the ability of the kidney cells to remove the uric acid exposed to them by the blood. That is, uric acid accumulates in the blood until an explosion occurs. But there must be, besides, some abnormality of production of uric acid. It is interesting to note that, as Taylor suggested, the sodium of salts of uric acid tend to precipitate out in the cartilage of joints because cartilage itself is very rich in sodium salts, which diminish the solubility of the uric-acid salt. On the other hand, sodium urate is three times as soluble in blood as in water. Alkalies are useful in gout because they probably act to assist in the formation of the potassium salt of uric acid, which is more soluble than the sodium salt.

Now, gout is definitely a disease of food and metabolism because it is alleviated by a low uric-acid-forming diet and made worse by a high uric-acid-forming diet. It is, therefore, a disease of limitation of the uric-acid tolerance, just as diabetes is a disease of limitation of the sugar tolerance.

The Origin of Uric Acid

But gout, as chronic gout, may affect the whole life history of a person without ever giving him any attacks of inflammation of the joints. It may manifest itself simply as vague disturbances of health, or as migraine attacks, as stomach and intestinal ailments, or as mainly a psychological twist of the personality. In all of these, careful examination shows an increased amount of uric acid in the blood and an abnormality of uric-acid metabolism quite like that of classical gout.

The uric-acid-forming capacity of foods must then be attentively regarded in any analysis of food. Particularly must it be considered in distinguishing between a high protein diet and a low protein diet. A high protein diet may be built upon either an animal or vegetable source. To advise

a high protein intake from a purely plant or vegetable viewpoint is often difficult because of the large bulk of material required. That is why a vegetarian diet, so-called, is frequently supplemented by the dairy proteins, cheese and eggs. But proteins of animal origin may have certain advantages. These animal proteins are the proteins of muscle—meat—and the proteins of the glandular organs—liver, kidneys, sweetbreads, and so on.

Now, it is through its connexion with meat that uric acid has become the most popularly known of all the chemical substances in the bodymind. At least, a feeling of familiarity is associated with mention of it because of the relationship. The relation, too, has made it the relished prey of quacks and pseudo-science concerning rheumatism and arthritis. Many ills and queer symptoms have been ascribed to it by legitimate practitioners of medicine which have been hotly discussed and argued. So it has been the reason for some of the most brilliant researches in chemical medicine. A cycle of intense interest in it has been followed by a cycle of apathy.

Uric acid was discovered in 1776 by Scheele in urinary stones. Between 1834 and 1848 it was the object of intense research by Liebig and Wöhler. They worked out its elementary chemical composition and obtained most of the products now known to form when its molecule is broken down by various methods. In the 1860's, Baeyer, who will be eternally famous for his synthesis of indigo, solved the problem of the constitution of most of these products of analysis and just missed synthesizing it. Horbaczewski accomplished this in 1882 by melting together urea and the amino-acid glycin. It remained, however, for Emil Fischer, most eminent penetrator into the secrets of the proteins and their amino-acids, to clarify completely the problem of the origin and derivation of uric acid in a series of investigations carried on over a period of twenty years.

Uric acid is derived from a class of proteins known as the 'nucleoproteins', soluble in alkali and insoluble in acid. These nucleoproteins are so named because they are the proteins which can be separated out of the nucleus of cells. Chemically the nucleus of a cell is its metabolic and synthetic centre. That is, the most complex chemical activities of a cell occur within the nucleus. Consequently, one would expect to find the most complex substances in it. The pro-

teins are the most complex of all known chemical compounds, and the nucleoproteins are the most complicated of all proteins.

These nucleoproteins are all compounds of certain simpler proteins with a most remarkable acid, called ‘ nucleic acid ’. And it is by way of its nucleic acid that a nucleoprotein comes to form uric acid. There are several nucleic acids, depending upon the source of the corresponding nucleoprotein, whether animal or plant. But they all have essentially the same chemical composition. They are compounded of a five-carbon sugar, pentose, phosphoric acid, and nitrogenous bases.

The nitrogenous bases of nucleic acid are all derivatives of a mother substance called ‘ purin ’, having the formula $C_5N_4H_4$. They are all, therefore, said to belong to the family of the purins and are referred to as the purins to describe them as a group. There are four of these purins : adenin, guanin, zanthin, and hypozanthin. *The end product of their oxidation in the tissues is uric acid.* It is, therefore, the purins of the nucleic acids of the nucleoproteins of foods which give rise to the problems of uric acid in the bodymind. The amino-acid histidine is the ultimate food source of the purins and nucleoproteins.

The Evolution of Uric Acid

Uric acid may then be said to be the end product of purin metabolism in man. It is also the end product of nucleoprotein metabolism in apes (another fact which will give pain to those who have set their hearts against admitting that man is a cousin of the apes). In all other mammals investigated, except, curiously enough, the Dalmatian dog, uric acid in turn is transformed into another substance, allantoin, by further oxidation. This allantoin is easily soluble in water and quickly excreted. In man uric acid must be got rid of, since nothing further can be done with it.

Why there should be this marked difference between man (and the other primates) and the other mammals, which has paved the way for the occurrence of so profound a disturbance of metabolism as gout, is a puzzle. It is perhaps connected with a fact of water metabolism, as suggested by Mathews. In mammals, amphibians, and fish the quantity of uric acid excreted in the urine is small and is but a small proportion of the total nitrogen output. In man, for instance, uric acid

represents between 3 to 10 per cent of the total nitrogen excretion, most of the latter consisting of urea. In birds and reptiles, though, uric acid takes the place of urea, and most of the nitrogen excreted is in the form of uric acid. In the invertebrates, also, and especially in the molluscs, most of the waste nitrogen is uric acid and its predecessors, the purin bases.

It is Mathews's suggestion that this difference in metabolism between the two great sets of land animals, the reptiles and their descendants, the birds, and the mammals and their ancestors, the fish, had as its object the conservation of water in the cells. The reptiles probably originated and developed in some very dry part of the land out of some amphibian. They replaced the moist skin of their ancestor with hard dry scales, which were best for preventing loss of water through their outer covering. As an additional adaptation to an arid climate they changed their metabolism. For as uric acid is almost insoluble in water, it needs but little of it, while urea is very soluble in water, combines readily with much of it, and removes quite a quantity when it leaves through the kidneys in the urine. It is interesting in this connexion that uric acid is not removed from the bird dissolved in its urine, but as clumps of crystals, very little water accompanying it. The bird is the only other animal besides man in whom gout has been reported, possibly because of this tendency.

At any rate, the insolubility of uric acid in water is an important factor in the production of gout. If there is a disturbance of water metabolism or of the purin chemistry or of both, uric acid will tend to accumulate in the blood and tissues. A state of saturation results, with a resulting tendency for it to separate out, in fact, to crystallize out, of its solution and to be deposited in the joints first and then in various other tissues.

On an average mixed diet the ratio of uric acid to urea in the urine is about one to sixty. Part of this uric acid originates in the nucleoproteins, nucleic acids, and other purin-containing materials of food. This is known as the 'exogenous' uric acid. But part of it, and a very significant part, is derived from the regular breaking-down of cells, including their nuclei, which is the cycle of metabolism. This is called the 'endogenous' uric acid. It is the amount of uric acid produced when the individual is taking no purin-containing food at all.

This endogenous uric acid is irreducible, fairly constant, and characteristic of the individual, remaining the same for years, even twenty or thirty years. It may be determined by putting the individual upon a purin-free diet, that is, food which contains little or no cells, such as sugar, butter, cream, milk, eggs, white bread, and potatoes. They contrast with the foods which contain many cells and large nuclei, such as meats, liver, kidney, yeast, and so on, and are naturally rich in purins.

That the endogenous uric acid is a measure of the actual metabolism of the nuclei of cells is proved also by the fact that a marked rise occurs in the uric acid of the blood when the destruction of cells is greatly increased. This happens in severe burns or in pneumonia. An increase of purin-rich food in a diet will do the same. It is also true that there is an augmented elimination of uric acid even on free-purin diet, if the total amount of food in general is increased. This occurs soon after eating. It is but another indication that all food stimulates metabolism to some extent, and accelerates the destruction of cells, which is part of the normal cycle of metabolism.

There is no more interesting story in the metabolism of foodstuffs in the bodymind than that of the degradation of the nucleoproteins into uric acid. The nucleoproteins in cells have long been known as 'chromatins' to microscopists because they stain with alkaline dyes. They have fascinated the student of heredity, for they break up during cell division to form the chromosomes which are the carriers of family qualities. There is a difference between the nucleoproteins of the male and that of the female because certain nucleoproteins in the germ cells transmit and determine sex.

In the stomach the crude nucleoproteins are broken down, simpler proteins like the histones and protamines being freed, and a less complex compound of nucleic acid and protein, known as a 'nuclein', being formed. In the intestine, the nucleic acid is split from the nuclein, and nucleic acid itself is absorbed by the intestinal tract, where it is further analysed into its primary building-stones, the nucleotids. These are carried to the liver and there, by a series of enzyme cleavages, the ultimate bricks of nucleic acid, the purins, as well as the phosphoric acid and the five-carbon sugar, ribose, are set loose. By a process of hydration and oxidation, the purins

finally become uric acid. The liver has the capacity to absorb much uric acid.

All the tissues and blood have a great capacity for uric acid and are capable of storing it. A certain amount of uric acid is, therefore, always present in them. Even if all nucleoprotein foods (purins) are excluded from a diet, a certain amount of uric acid is constantly manufactured by the dissolution of cells in the metamorphoses of metabolism, such as that by which skin cells form the horny layer or bone marrow cells make the unnucleated red cells of blood. As long as the individual's basal metabolism remains constant, his output of this, the endogenous uric acid, remains a definite fixed quantity, beyond his control. It is true that the liver can keep within itself the precursors of uric acid, which it may suddenly mobilize into the blood and upset the equilibrium characteristic of the normal individual. But all other things being equal, the uric-acid content of the blood and the other tissues is a pretty fixed figure in the normal person.

The Appraisal of Purin Tolerance

The purin tolerance is a conception involved in the consideration of uric-acid metabolism analogous to that of sugar tolerance, fat tolerance, or protein tolerance. It can be determined, as they are determined, by subjecting the cells of the bodymind to an excess, in this case, of purin-containing food, and observing the reactions and adjustments of the organism. The gouty, or those predisposed to gout, or those who have a disturbance of their uric-acid chemistry similar to gout, may all thus be tested to measure their common limitation.

It is most convenient to carry out a test of purin tolerance by feeding at a single sitting a large quantity of liver or sweetbread, either of which contains a large amount of nuclear material generating much purins and uric acid. The testee is first put on a purin-free diet for two days, if he has shown signs of abnormal uric-acid metabolism. Otherwise, the test may be done on the ordinary mixed diet. The uric-acid content of the blood and urine are determined under standardized conditions. If the subject tested has been upon a low purin, low protein, low calorie diet for several days, the uric-acid content of the blood and urine become constant. The examiner may then be fairly assured that he is acquainted

with the level of the *endogenous* uric metabolism. Then the purin-test meal is given.

Three possibilities are available. One is that the uric-acid content of the blood and urine lies within the normal range. The reactions to the purin-test meal consists in a rapid increase in the uric-acid content of the blood and urine, and then a quick return to the previously normal concentrations. A second possibility is that the uric-acid content of the urine is higher. This is a condition called 'diabetes uricus', similar to diabetes insipidus, in which there is a decrease of the water content of the blood and a great increase of it in the urine. It is also similar to diabetes albuminuricus, in which the protein content of the blood is low, while the protein content of the urine is high. The reaction to a purin-test meal in diabetes uricus is that the uric acid of the urine increases, while the uric-acid content of the blood remains low. The third possibility is what occurs in gout (or in latent gout, called the 'uric-acid diathesis'). Here the uric acid of the blood increases, while the uric-acid content of the urine remains low.

In gout or in the gouty, uric-acid diathesis, the uric acid of the blood is above normal, under all conditions of diet, exercise, and general régime of living, with very few exceptions. During attacks of gouty manifestations, there is a marked increase in the uric acid of the blood, high as it may have been before, followed by a lowering. It is as if one function of the attack was to rid the blood and tissues of as much uric acid as possible. The amount of uric acid in the urine increases as the blood uric acid drops. There is at the same time an increase of the phosphoric-acid content of the urine. This points to a common origin in accumulated nucleic acid or nucleic-acid derivatives containing purins and phosphoric acid. The uric acid of the blood and urine simply mirrors what is happening to the total nucleic-acid metabolism.

There is thus demonstrable a definite difference in the way the gouty and the non-gouty respond to an increased purin supply. If nucleoprotein food is ingested by a person with a normal uric acid and metabolism who has been upon a purin-free diet, about 50 per cent of the extra purin will pass through the kidneys in the next day or two. In the gouty individual the excretion of the purins takes much longer, and only from about 10 to 25 per cent can be detected

in the urine as uric acid. In both, the blood uric acid increases immediately after the high purin meal. But in health the increase is only temporary, and reverts to the normal as the uric acid is removed through the urine. This tendency of the gouty to retain purins and to register the retention in blood by a sustained rise of its uric acid is the characteristic diagnostic feature of their abnormal metabolism.

Even on a purin-free diet the urine of the gouty generally presents the picture of a quite high uric-acid content. Just before a gouty attack, however—no matter what the manifestation may be—the uric acid of the urine falls, as if the kidneys were failing to excrete it. Then, as the attack culminates, the uric-acid output rises to a figure much above the usual, then drops again gradually as the attack subsides.

The precise nature of gout, the mechanics of its manifestations, is still a mystery. Two main questions must be answered to provide a satisfactory answer to its provoking problem. First, why is the uric acid in the blood and tissues increased? And second, why is it deposited in the cartilages of the small joints preferentially, as well as in other joints and tissues? Only probabilities may be stated as an explanation of these main phenomena of the disease and its underlying predisposition or diathesis, which undoubtedly occurs in many apparently normal individuals who never have attacks of gout.

The liver is the chief storehouse for most of the uric acid released by the digestion of the nucleoproteins of food. When uric acid is injected into the blood, about 50 per cent is almost immediately removed and stored in that organ. There is an equilibrium between the uric acid of the blood and the uric acid of the liver. The greater the quantity of uric acid in the liver, the higher the level of uric acid in the blood. As the blood uric acid continues high in gout even upon a purin-free diet, we must assume that the endogenous uric-acid metabolism of the individual is abnormal, producing a state of quasi-saturation of his tissues with it. An orgy of some sort, liquid dietetic or emotional, affects the vegetative nervous control of the uric-acid content of the liver, possibly by means of hormones like adrenalin or pituitrin, throwing a large amount of uric acid into the blood. The same nervous upheaval causes a depression of kidney excretory power for uric acid. The total result is a saturation of these tissues

with uric acid which have already approached the saturation point. The joints affected seem to be the sites of predilection, having probably a greater affinity for the uric acid because of some special local condition of circulation or chemistry. A reaction of other tissues may be explained in the same way.

The Relation of Uric Acid to the Ductless Glands

Now, as the ductless glands are the specific regulators of metabolism, and gout is a definite disturbance of bodymind chemistry, the problem presents itself: What, if any, are the imbalances in the ductless-gland system responsible for the abnormalities of purin metabolism? No entirely acceptable information is at present available that may be considered a solution of the problem. But certain facts are worth noting that throw light on what may turn out to be the underlying difficulty of the uric-acid elimination.

Falta found that in hyperthyroidism the endogenous uric acid was quite low. Also that the exogenous uric acid, that produced by the ingestion of meat, was also quite low. Falta drew the conclusion that, under the influence of an excessive thyroid action, the ability of the bodymind to decompose uric is increased. In striking contrast is the fact that in thyroid deficiency the level of the endogenous uric acid tends to be higher and the excretion of assimilated purins is slower. Removal of the thyroid will result in a tendency to uric-acid retention. The feeding of iodine tends to produce the same effect. There is a form of rheumatism associated with thyroid deficiency which may be related to gout.

The adrenal glands have a profound influence upon uric-acid metabolism. Adrenalin injections increase markedly the uric-acid content of the blood. The same is true of whatever other procedure will cause an increase of the adrenalin content of the blood—pain, emotion, cold, exercise, and certain diseases of the brain. When adrenal extracts, spleen extracts, or pancreatic extracts are administered, the uric-acid content of blood and urine rises. And the sex glands in particular seem to exert a special influence in facilitating the removal and destruction of the purins. Pineles has described families with gouty joint pains, the members of whom showed signs of some sexual arrest of development.

The German clinical observer, Lindemann, has emphasized

that all his cases of irregular gout presented signs and symptoms of disturbances of the glands of internal secretion in general and of the thyroid in particular. The most striking of these consisted of anomalies of menstruation, tendency to enlargement of the thyroid, and changes in the blood. At the same time, there was marked instability of the sympathetic nervous system, easily demonstrable by various methods. According to Cole, Womack, and Ellett, the methyl purins, like caffeine and theobromine, produce a hypertrophy of the thyroid similar to that of toxic goitre.

But of all the ductless glands, the one which accumulating evidence seems to implicate more definitely in uric-acid metabolism, and therefore in gout, is the pituitary.

Uric Acid and the Pituitary Gland

Several facts have been established concerning uric-acid metabolism and the pituitary gland which have a bearing on purin tolerance. One is the observation that the uric acid of the blood tends to be strikingly increased, almost doubled in pituitary-gland disturbances. This is much more than has been observed in any condition except kidney disease, when it is simply the result of an inability to excrete it. Another is that individuals with defective pituitary glands have a lowered tolerance for purins. Thirdly, pituitrin will mobilize uric acid from the purin depots of the tissues.

The fat boys and girls with undeveloped sexual organs, who have Froehlich's disease, show a subnormal quantity of uric acid in the urine which is only slightly increased after the administration of purins. That is, their bodymind has difficulty in both mobilizing and removing purins. On the other hand, in acromegaly, in which the pituitary is functioning excessively, the endogenous blood uric acid is high and elimination of ingested uric acid or purins is prompt.

All the available evidence makes it quite probable that there is a direct proportionality between purin tolerance and the efficiency of the pituitary gland. Other endocrine glands play a secondary part. Sex-gland deficiency involves a lowering of nucleoprotein tolerance as does thyroid deficiency. But the participation of the pituitary in the problem of uric-acid tolerance is so definite that there can be no question that the solution of the problem of gout must somehow be associated with it.

Limitation of the purin foods in patients with pituitary disease, as one would in gout, assists in the therapeutic control of its manifestations. Also the pituitary has been implicated in every case of gout in whom I have made an ' endocrine assay ', a functional study as to how each of the endocrine glands was working in that particular person. My own personal judgement is that gout is a disease which will be proved to be due to some effect of the pituitary upon the proper functioning of the liver.

Limitation of the purin tolerance has been found, not only in gout, but also in migraine, asthma, mucous colitis, and neurasthenia, with associated signs of disturbances of the liver and the pituitary. Members of the same family tend to have about the same purin tolerance. But marked differences have been observed between apparently normal individuals of the same family.

The Relation of the Purins to Genius

Returning now to the problem of the relation of gout to genius, the problem is seen to be reduced to questions involving purin metabolism and the uric-acid content of the blood and tissues. At the same time, it has been shown that there is a relationship between the pituitary gland and the purin chemistry of bodymind. In his book, *The Glands Regulating Personality,* in a chapter on ' Historic Personages ', including Napoleon, Darwin, and Nietzsche, Berman presented evidence that genius tends to be associated with a superiorly functioning pituitary gland which is somewhat unstable, tending to have periods of insufficiency. Such an instability, a periodic insufficiency of the gland, might well explain the paroxysms of gout or gouty manifestations (metabolic surrogates or substitutes) in men of genius.

Havelock Ellis is only the last of a long line of observers, dating back to the Greek physician of the second century, Aretæus, who have remarked on the connexion between supreme ability and the gouty constitution. He quotes the English physician Chalmers Watson as stating that gout ' is peculiarly incidental to men of cultivated mind and intellectual distinction '. And Ellis himself goes on to say:

> It would probably be impossible to match the group of gouty men of genius, for varied and pre-eminent intellectual ability, by

any combination of non-gouty individuals on our list. It may be added that these gouty men of genius have frequently been eccentric, often very irascible—' choleric ' is the term applied by their contemporaries—and occasionally insane. As a group, they are very unlike the group of eminent consumptives. These latter, with their quick sensitiveness to impressions, often appear the very type of genius. The genius of the gouty group is emphatically masculine, profoundly original; these men show a massive and patient energy, which proceeds not only ' without rest ', but ' without haste ', until it has dominated its task and solved its problem.

This association of ability and gout cannot be a fortuitous coincidence. I have elsewhere suggested (*Popular Science Monthly*, July, 1901) that the secret of the association may possibly to some extent lie in the special pathological peculiarities of gout. It is liable to occur in robust, well-nourished individuals. It acts in such a way that the poison is sometimes in the blood and sometimes in the joints. Thus, not only is the poison itself probably an irritant and stimulant to the nervous system, but even its fluctuations may be mentally beneficial. When it is in the victim's blood, his brain becomes abnormally overclouded, if not intoxicated; when it is in his joints, his mind becomes abnormally clear and vigorous. There is thus a well-marked mental periodicity; the man liable to attacks of gout is able to view the world from two entirely different points of view; he has, as it were, two brains at his disposal; in the transition from one state to another he is constantly receiving new inspirations, and constantly forced to gloomy and severe self-criticism. His mind thus attains a greater mental vigour and acuteness than the more equable mind of the non-gouty subject, though the latter is doubtless much more useful for the ordinary purposes of life, for the gouty subject is too much the victim of his own constitutional state to be always a reliable guide in the conduct of affairs.

I have sometimes found that physicians, who readily accept a special association between intellectual ability and gout, are inclined to account for it easily by an unduly sedentary life probably associated with excesses in eating and drinking. This explanation cannot be accepted. Many of the most gouty persons on my list have been temperate in eating and drinking to an extreme degree, and, while it is true that the gouty have often written much, the general energy, physical and mental, of the gouty may almost be said to be notorious. Sir Spencer Wells, in questioning the influence of sedentary habits, referred to the remarkable activity of gouty statesmen, and Dr. Burney Yeo remarks (*British Medical Journal*, 15th June, 1901): ' The gouty patients that I have seen have, I should say, in the majority of instances, been extremely active and energetic people, and it is

often difficult to get them to take sufficient rest.' I may note that in a much earlier age Aretæus speaks of a gouty person who, in an interval of the disease, won the race in the Olympic games.

It may be of interest to point out, in relation to the connexion between genius and gouty conditions, that Marro (*La Puberta*, p. 256) has observed a very constant relation between advanced age of parents at conception and lithiasis in the child. We have already seen that there is a marked tendency among some of our men of genius for the parents to be of advanced age at the eminent child's conception ; and it is possible that the connexion between gout and genius may thus be in part due to a tendency of some of the gout-producing influences to be identical with some of the genius-producing influences. If this is so, we might probably expect to find the age of the parents of those of our men of genius who belonged pathologically to the lithiasis group would be higher than the general average. I find that the average age of nineteen fathers of eminent gouty men is 37·4, and of seven mothers 33·2 years, while the average age of eight eminent men who suffered from stone or gravel is 37·2. These averages are slightly, but very slightly, indeed, higher than those for our men of genius generally. It must, of course, be remembered that the general averages are higher than those for the normal population.

It must not in any case be supposed that in thus suggesting a real connexion between gout and genius, it is thereby assumed that the latter is in any sense a product of the former. It is easy enough to find severe gout in individuals who are neither rich nor wise, but merely hard-working manual labourers, of the most ordinary intelligence. It may well be, however, that, given highly endowed and robust organism, the gouty poison acts as a real stimulus to intellectual energy, and a real aid to intellectual achievement. Gout is thus merely one of perhaps many exciting causes acting on a fundamental predisposition. If the man of genius is all the better for a slight ferment of disease, we must not forget that if he is to accomplish much hard work he also requires a robust constitution.

It may be added that the other diseases usually described as of the uric-acid group are common among our men of genius. Rheumatism, indeed, is not mentioned a large number of times (eleven), considering its prevalence among the ordinary population. But stone, and closely allied conditions, are mentioned twenty-five times (sometimes in association with gout), and as we may be quite sure that this is a very decided underestimate, it is certain that the condition has been remarkably common.[1]

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[1] *A Study of British Genius*, p. 168.

Why Purin Abnormality Stimulates the Brain

Assuming, then, as proved that an abnormality of purin metabolism stimulates the brain, the mechanism of this stimulation remains to be explained. And a number of researches should be done before positive answer to the question raised can be given. As, for example, a comparison should be made of the uric-acid content of the blood going to and from the brain, and a study of the purin content of the brains of eminent men as compared with that of ordinary men. But a tentative explanation may be offered which co-ordinates everything that is known about the subject.

Certain derivatives of the purins are universally recognized as brain stimulants. Of these the most widely used is caffeine, the active principle of coffee. When caffeine is ingested, it is excreted as uric acid. In other words, the bodymind treats it as a precursor of uric acid. May not all the precursors of uric acid have a caffeine-like action upon the brain ?

The relation between purins, the precursors of uric acid, uric acid, and caffeine is very close. Caffeine, in fact, is one of the purins, and may be synthetically derived from them. One of the purins, zanthin, is the direct precursor of uric acid, for uric acid may be made from it by the addition of oxygen. Uric acid is a trioxy-purin, while zanthin is a dioxy-purin. Caffeine is zanthin modified by the addition of three methyl radicals. In other words, caffeine is a pre-uric-acid substance.

To put it another way, caffeine is a methylated derivative of zanthin, which in turn is uric acid minus an atom of oxygen. Such additions and subtractions of oxygen are known to be going on constantly in cells. Moreover, methylations (the addition to compounds of the radical CH_3) are also known to be occurring. What is more reasonable than to suppose that an abnormal production, retention, or deposition of purins in the brain will result in the formation of caffeine or caffeine-like substances, which, acting continually and in small amounts, stimulate the oxidations of the brain to their highest capacity ? Also, these caffeine-like substances may stimulate the brain indirectly through their effect upon the thyroid, increasing the production of thyroxin, as above mentioned.

This supposition is borne out by the fact that caffeine and caffeine-like substances are the only ones definitely discovered

to be brain stimulants and to be so employed the world over. These purin derivatives are found in plants growing in different parts of the world, plants with intimate botanical kinship. But wherever they do grow, the inhabitants have discovered their particular value as stimulating beverages. Their usage has come to be a part of the daily dietary practices of many peoples.

Thus, among the Arabians and the Egyptians the established stimulating drink is made by toasting the coffee seeds. In Western Africa, the dried seeds of cola are used. In China and Japan, India and Russia, fermented tea leaves furnish a beverage containing theine, a close relative of caffeine and having the same effects. Among the Brazilians the drink is brewed from guarana, a dried mass manufactured by grinding the seeds with a little water and then drying. In Southern South America, in Uruguay and Paraguay, there is maté, the desiccated leaves and buds of a species of holly, while the Appalachian North Americans used another species of holly, the Ilex cassine, which makes a very weak solution of caffeine. In Mexico and the West Indies, where there are no caffeine-containing plants, the natives ferment the seeds of the chocolate, which gives them a potion of theobromine, a chemical relative of caffeine.

All things considered, it becomes plausible to conceive of the brain of the gouty or those with a disturbance of the purin metabolism as bathed by blood containing caffeine-like precursors of uric acid. Such brains are then being constantly subjected to a special chemical stimulation, an auto-stimulation rather than an auto-intoxication, which may account for their superior achievements. All the data favour this view and nothing opposes it.

If it is true that the purins act as stimulants of the central nervous system, care should be taken not to exclude a certain amount of them from the diet, except in genuine gout or in individuals with evidence of excessive accumulation of uric acid in the blood. Certain cases of mental sluggishness and disability may be greatly benefited by a diet rich in purins. In practice this means a meat diet. Herbert Spencer once wrote: 'I tried vegetarianism for three months and found I was obliged to destroy everything I wrote during that period because of a lack of meat.' Spencer was a congenital carnivore, with pituitary instability, who needed the purin

stimulation for his cerebral activity. On the other side, George Bernard Shaw, a congenital vegetarian, has put on record again and again the devastating effects of meat upon his own creative production. As he wrote in one of his letters to Ellen Terry: 'The odd thing about being a vegetarian is not that the things that happen to other people don't happen to me—they all do—but that they happen differently; pain is different, pleasure different, fever different, cold different, even love different.' In either case, the necessity of considering the nutrition of the brain as a special constitutional problem becomes evident.

CHAPTER XII

THE NUTRITION OF THE BRAIN

THE brain is the supreme organ of bodymind because it is the medium of consciousness and unconsciousness. Its cells function to co-ordinate the organs and muscles for the control of the environment. It gives the individual his sense of himself *as a whole.* Thereby it becomes the instrument of *behaviour as a whole.* From the unsolved mysteries of its chemical reactions emerge the materials of character: perceptions, thoughts, emotions, moods, and determinations.

Now, as the endocrine glands are influenced in their chemistry and functions by food, they react upon character through their effect upon the brain and the nervous system. The brain has its own characteristic metabolism which expresses itself in memory, reasoning, judgement, imagination, and the creations of the conscious and unconscious mind. In the ultimate analysis, the achievements of a Shakespeare or a Shaw, a Newton or an Einstein, a Plato or a Whitehead, are the resultants of chemical reactions in their grey matter. That we cannot conceive the process by which they crystallize as the *Ulysses* of James Joyce, the *Brothers Karamazoff* of Dostoyevsky, or the *Magic Mountain* of Mann, is a limitation of our understanding. In effect it is the same as our inability to visualize the concepts of modern physics.

But of one principle there can be no doubt, scientifically speaking. The activities of the 'I' are dependent upon the chemical properties of the brain.

The Aristocrats of the Bodymind

The brain cells may be said to constitute the ruling class of the Bodymind Commonwealth. But they are as much subjects to the whims and passions of their servitors as rulers of them. Thus, the position of the brain resembles

that of the president of a republic rather than of the dictator of an empire.

All other organs function to serve the brain as their master. It governs, directs, and uses them. For example, consciousness obtains food for the stomach, which in turn digests to feed the brain. Yet, this master may be, and in fact is, continually being disturbed, irritated, or even poisoned by the muscles and viscera it serves. But without them it would be a Hamlet on a desert island. Without muscles and organs it would be incapable of emotion, dying of its own stagnation—a frigid vault of hoarded memories. On the other side, if it be damaged slightly and consciousness lapses, the individual becomes an automaton, and the organs and muscles die unless it is quickly restored.

The brains of individuals differ in quantity and quality. Together these make up brain power. To experience and remember the countless items of the universe, perpetually impinging upon consciousness, there must be as many brain cells as possible—a matter of quantity. To deal with and control those experiences in all their startling complexities, it must shift and change the condition of the cells, separating them and combining them with flexibility, versatility, and agility—a matter of quality.

Apart from chance and favouring luck, it is brain power that has decided the survival of the fittest among living things. In the conflict of intelligence with environment, the brain has been subjected to the greatest stress of evolution. Animals may be graded upon the basis of brain power, all through the evolutionary series, from amoeba to man. Man is at the top, as the possessor of the largest and most complicated brain. The best brain is at once the most adaptable and the most dominating in relation to its problems.

The whole urge of evolution has been to obtain greater control of the environment and at the same time to achieve independence of it. Through it brain has emerged as the centre of bodymind. And the ductless glands of internal secretion have assisted considerably in the process. They have evolved to maintain the bodymind and especially the brain in an almost constant temperature and a more or less fixed blood chemistry. Thus, the brain has been freed from responding precipitously to a change in the heat of an environment by a drop or rise of temperature. Nor does it have to

concern itself with the incontinent loss or access of an important chemical like sugar.

Also, the brain arranges a relative freedom for the psychic reactions. Because of its powers of adjustment, an emotion does not sweep the organism to destruction. Nor does a problem of food, sex, or escape provoke it to suicide. These psychic problems are by far the most important in the life history of an organism. Therefore, the pressure of the evolutionary forces has been exerted upon the development of the nervous system and the brain.

A notable instance of the working of the principle—develop brains or die—is the extinction of those huge monsters who once roamed the earth as Lords of Gluttony—the Dinosaurs. Their relatively tiny brains could not cope with their smaller but smarter competitors. It was the latter who grew grey matter when conditions changed and the struggle for food grew keen.

All the organs of bodymind represent specialties that were once general to any primeval protoplasm. The lungs are the specialists in the capture of oxygen, a function in which the skin was once active and of which all primitive cells are capable. The organs of sex are the specialists in reproduction, and the muscles are the experts in movement. The nerve and brain cells are the authorities in adaptation which occur by learning, remembering, managing, and solving problems.

The brain acts like a net. It catches the assimilables and rejects the unassimilables of the universe. This specialization in one direction means a loss of power in all others. These brain cells that can react so wonderfully cannot move significantly nor grow and reproduce themselves.

By studying the chemistry of the brain cells, we may hope to find what chemical substances of the nerve protoplasm are concerned in its functions and powers. Thus a clue may be provided as to how they are related to food.

The Resurrection of Phosphorus in Brain Chemistry

One of the earliest discoveries about the chemistry of the brain showed that it yielded a large amount of phosphoric acid. Finer analysis proved that this phosphoric acid was present as phosphates; also, as combinations with sugar and protein as nucleoproteins; also, as compounds with

proteins alone, phosphoproteins. But it is mostly conjoined with the peculiar fat-like substances known as the 'lipins' or 'lipids'. Of these the cholesterols and the lecithins are the prototypes. Collectively, these compounds of phosphorus and the lipins are named the 'phospholipins'. The lecithins are typically found in yolk of egg. The cholesterols were first discovered in gall stones.

Upon the basis of the occurrence of so much phosphorus in the brain, Moleschotte and Liebig popularized the epigram: 'There can be no thinking without phosphorus.' Thus started the tradition that phosphorus and foods containing it are good for one who leads a brainy life. There can be no doubt that phosphorus has a definite relation to the chemical composition of the brain and its performances. But we must look for more specific information regarding the chemical compounds of phosphorus unique to the brain before we can begin talking about the value of it as a brain food.

Brain cells are grey and are known as 'grey matter'. Their fibres are white and are known as 'white matter', because they are overlaid by a sheath of whitish-appearing 'myelin'. Water is present in the grey matter to the extent of 85 per cent, in the white matter the proportion is 70 per cent. Of their solid matter, the most important constituents are the substances which are not ordinarily soluble in water, but in alcohol and ether. These are the phosphorized fats, the phospholipins of which so much is present in the brain.

This solubility of their substances in alcohol and ether rather than in water distinguishes nerve tissues sharply from all others, most of the contents of which are water-soluble. It suggests that the properties characteristic of the brain are connected with the presence of these remarkable compounds of oxygen-poor fats with phosphoric acid. That they increase in amount proportionately to the degree of complexity of the nervous system as it gets older and more learned also supports the view of their importance.

How the Linolinic Acid of Linseed Oil Learns and Forgets

Because of the presence of these phospholipins, Mathews has pointed out an interesting analogy between the chemistry of painting and the process of brain remembering. Linseed oil is used as a medium for paints. Linseed oil resembles

the phospholipins in that it is oxygen-poor. It has the capacity for taking up oxygen. It is used in painting because it oxidizes spontaneously when exposed to air and light. It changes thereby from an oily liquid to a resinous solid which protects the painting from the destructive action of the outside elements.

Because it oxidizes, linseed oil may be said to breathe. It takes up oxygen, gives off carbon dioxide, and heat is produced. The reaction is speeded by ultra-violet light, also by catalysts which the painter calls ' driers '. These are salts of iron, manganese, and turpentine. They act as oxygen transmitters. Another similarity is that, like the effect of ultra-violet light, iron and manganese are catalysts in living protoplasm. Also a resin accumulates. In a sense, then, linseed oil, mixed with chemicals and catalysts, *metabolizes* like living matter, breathing, consuming substance, and leaving a residue.

But this linseed oil also seems to learn like living nerve tissue. If it is stimulated by ultra-violet rays, no reaction apparently occurs for twenty-four to thirty-six hours. Then the oil takes up oxygen slowly, then more quickly as if learning better and better as time went on while it was oxidizing itself. The reaction is a characteristic auto-catalysis or self-catalysis in which a first product of the interactions of substances speeds the course of the whole. Many such have been described in living cells. And it has been supposed that the process of learning is some such affair of auto-stimulation by auto-catalysis. At any rate, the curve of learning and the curve of auto-catalysis are much alike.

The linseed-oil-oxygen-ultra-violet-light systems not only may be said to learn, but also to remember and forget. If, after being treated with the light rays for a time and the linseed oil is oxidizing quickly, the lamp is withdrawn, the oxidation becomes slower. But, if the light is turned on again after a few hours, the oil no longer waits to speed up, but increases its rate almost immediately. If, though, it is left in the dark twenty-four hours, it seems to forget. And when the light is turned on again, another twenty-four hours have to elapse before it begins to oxidize more quickly. Chemically, the phenomenon is explained as due to the appearance or disappearance of intermediate substances ; the auto-catalysts, with the presence or absence of light.

This resemblance to learning, remembering, and forgetting

is remarkable. The analogy is reinforced by the occurrence in the brain of large quantities of the lipins, which are much like linseed oil. Protoplasm in general may learn and remember for a time because of the formation of these auto-catalysts. Because they are left-overs of chemical reactions of stimulation, they may hasten the reactions characteristic of them the next time similar substances or experiences are fed to cells containing them. Samuel Butler contended all his life that growth, learning, and memory are identical. Modern psychology is proving that his contention is correct.

The brain cells may remember better because they have the greatest amount of remembering, catalyzing substances—the lipins. They may remember longer because they have the best facility for preserving these same substances arranged in patterns. That these lipins have a peculiar capacity for forming liquid crystals, chemical patterns which yet remain fluid, is also most suggestive. But more so is the fact that nerve cells do not divide or reproduce after maturity, nor do they change in chemical composition easily like other cells. This is again suggestive of a mechanism which preserves substances in patterns. When nerve cells disappear, as a result of injury, memories vanish too. This makes it certain that memory is inseparably associated with substances in the cells.

Unsaturated Fatty Acids Essential to the Normal Diet

Now, as to the problem of eating for the best nutrition of the brain: What is the relation of these chemical fats of the brain to their oxygen-poor, unsaturated fatty acids, like linolinic acid? What attention should be paid to individual needs and capacities for a high phospholipin or a low phospholipin diet? A high unsaturated fatty-acid or a low fatty-acid diet? How would differences in such diets affect mental fatigability—the ability to concentrate?

Until recently, the fat or lipin content of a diet was considered of no material consequence, provided it was adequate in all other respects. The fat-soluble vitamins were considered important, but the fats themselves were looked upon simply as a source of calories. They were regarded as completely replaceable by sugar and other carbohydrates.

All such views are obsolete since the findings of the Burrs published in 1930. They have demonstrated that a diet

lacking in unsaturated fatty acids, like the linolinic acids, is most injurious. Such fatty acids are needed for proper growth. Without them animals become small and emaciated and peculiarly thirsty. They drink more water than the control animals, which points to some injurious effect upon the post-pituitary gland. Kidney injury appears early. The degeneration is increased in severity by giving an accompanying high protein diet.

The production of ova in the mature female becomes irregular or ceases, which relates these fats to the endocrine activities of the ovaries. Females will mate in spite of the absence of ovulation. But males generally will not even mate. The males which do mate will not sire their offspring as the properly fed controls do. In fact, all the normal sex responses of the male are lost as a consequence of the unsaturated fatty-acid deficiency.

Rats thus affected cannot be cured by the feeding of saturated fatty acids, such as stearic or palmitic. But they are cured by linoleic acid either pure or combined. A mixture of the unsaturated fatty acids, as occurs in corn oil, linseed oil, or olive oil, seemed to be more effective curative agents than a single fatty acid. Warm-blooded animals cannot synthesize appreciable quantities of these fats, which makes it imperative for them to obtain them in food.

Now, no observations have been recorded as yet regarding the effect on the brain mass of a linolinic-acid deficiency. But in view of what is known of the predominance of these acids in the phospholipins of the brain and of their possible relation to the intellectual functions, it seems probable that a certain quotient of these will turn out to be of the utmost importance as a brain food. That is, a food that is intended to be adequate and optimal food for the best kind of brain and nervous system. In the present state of our knowledge, it is not yet practical to estimate individual needs. It is safest to incorporate a large proportion of unsaturated fatty acids in the diet until a test for the nutritional range of the phospholipins is available. They are present in olive oil, lard, egg yolk, corn and linseed oil, as well as brain and animal fat.

The Brain Sugar, Galactose

In distinction from the phosphatids just mentioned, there is another group of fats in the brain—the cerebrosids. They

are compounds of fatty acids, nitrogen, and a characteristic carbohydrate, a component of sugar of milk, lactose. It is the simple sugar 'galactose'. Cerebrosids differ from phosphatids (phospholipins) in the absence of phosphorus and the presence of galactose. Typical cerebrosids of the brain are phrenosin and kerosin. The corresponding fatty acids are known as 'phrenosinic' and 'lignoceric' acids. These two, the phosphorus-containing fats (phospholipins) and the galactose-containing fats (galactolipins), make up the bulk of the white matter of the brain.

Because of the presence of galactose, these cerebrosids should be considered in any diet especially intended to influence the brain. Particularly is this true of growing children. For the cerebrosids, not found in the embryonic brain, form as the nervous system develops. They are deposited in the sheaths which grow alongside the nerves. The process, designated as the 'medullation of the nerve fibres', makes the so-called 'white matter' of the brain as distinguished from the grey matter. As education proceeds, this process of medullation and increase of white matter follows.

The baby learns more things in a week than it does later on in a year. It is interesting to note that milk, the food of the new-born during the time when its brain is evolving at its most rapid rate, should contain so much galactose. Galactose is a building stone for the maturing nerve tissue. Human milk, while restraining growth of the rest of the body, seems to facilitate growth of the brain. So, it is an ideal brain food for the new-born. It contains more lactose than cow's milk. Mathews has suggested this as the reason for greater brain development of human beings. In children and grown-ups the tolerance for galactose is limited. It is increased when there is a deficiency of the post-pituitary gland. This may be used as a test of the functional efficiency of the post-pituitary.

As to fats, human milk has an average of 5 per cent, while cow's milk has only 4 per cent. When attempting to make a fat for a good artificial milk that resembles human milk, olive, coconut, cod-liver oil, and beef fat have been mixed. But even that mixture was sufficiently different from the fats of human milk to make a definite difference in the growth of the child.

As to proteins, human milk is also qualitatively different. So, it is a blow to our moderns to learn how impossible it is to imitate human milk with cow's milk and other mixtures to make it the food it ought to be. And even milk of human origin is not always adequate. For, when the mother is fed on an unbalanced diet, her milk reflects the defects.

Myelin, the Insulator

Now, the chemical organization of the brain means everything for its growth and education. The process of myelin deposition with medullation of the nerve fibres is of tremendous importance for the future personality. In the first six weeks of life, myelin (with its cerebrosids and phosphatids) is quickly deposited along the outside of the nerves of the brain.

All the nerve fibres are closely packed, running together like the wires of a cable. Each fibre originates in the nerve cells of the brain and spinal cord. It is the central core, called the 'axis cylinder', which conducts and transmits the energies of the nerve cell. At birth these cylinders are bare, like uninsulated wires. When these cylinders are used, they must be covered to prevent spread and radiation of the nerve impulses which would produce something like 'static'. Static would interfere with the balanced co-ordinations of nervous communications, the secret of brain organization.

Myelin seems to act as a protective insulator. It is secreted by the nerves around their axis cylinders. After the nerve has entered the tissue upon which it is to act, the impulses may diffuse. So the insulator is no longer needed. And the myelin sheath is actually lost. In one disease, multiple sclerosis of the brain, there is a loss of co-ordination due to a disturbance of insulated conduction. Although the axis cylinders remain unaffected, the myelin sheaths are destroyed. It may be a diet disease: a deficiency of some necessary but insufficiently supplied food element, necessary for the maintenance of the integrity of the myelin sheaths.

There is no reserve sugar other than the galactose of the cerebrosids in the brain. Nor is there any neutral fat. The brain is dependent for its sugar upon the blood continually circulating through it.

Sources of Energy of Brain Work

The brain has a higher metabolism than that of any other tissue in the body. Consequently, it has a greater need for oxygen. The unsaturated fatty acids, poor in oxygen, have a tremendous avidity for oxygen. Undoubtedly their prevalence in the brain is connected with the oxygen-consuming power of its cells. There are times when the brain cells do not receive sufficient oxygen direct from the blood. But, even though the oxygen income is not enough to make consciousness possible, the brain cells can continue alive for a while.

Unconsciousness is the first symptom of insufficient oxygen. Because of a lack of oxygen in the brain, death will result long before the other tissues show the effects. Ether and chloroform have the power to dissolve phosphatids and cerebrosids. In surgical anaesthesia, the state of insensibility to pain is probably achieved either by ether or chloroform because they interfere with the oxygen consumption of the highest brain cells which mediate consciousness, through their effect upon the combinations between oxygen and unsaturated lipins.

Undoubtedly, the distinguished effects of alcohol upon the brain are due to its capacity to influence the metabolism of the higher cells. But it is not in the same class with ether or chloroform. Atwater and Benedict have shown that over 98 per cent of ingested alcohol is burned to carbon dioxide and water. But large doses of it produce effects resembling those of all other narcotics.

Moderate doses of alcohol do not affect the total oxygen metabolism, although there is a local action, first stimulating, then depressing oxidation. There is a sparing of protein and sugar, with moderate doses, which diminishes metabolism. With larger toxic doses, the basic metabolism of the cells is disturbed—there is an increased elimination of ammonia, purins, and neutral sulphur. Also there is a tendency to retain chlorides.

Because of its influence upon the chemistry of the brain lipins, alcohol is a means discovered and used the world over for changing the personality. Its effects can be counterbalanced by administering large quantities of phosphatid- and cerebrosid-containing food.

Now, how is the brain able to attract, hold, and burn the enormous quantities of oxygen it uses per minute? According to Koch, the phosphatids and cerebrosids do not occur separately, but in combination, linked by sulphur. This sulphur, occurring in the sulphatids or sulpholipins of the brain, will probably turn out to be the important factor for the breathing of the brain. It has been recently shown that sulphur combined with hydrogen, as the sulph-hydryl radical, is dominant in the oxygen-consuming activities of cells. Both respiration and growth, according to Hammett, are dependent on it.

Dementia praecox is a form of insanity in which a complete dilapidation of the personality develops. Waldemar Koch found in this disease a marked decrease in the sulphur and little change in the amount of phosphorus of the brain.

Only oxygenated brain tissue is conscious and sensitive. The amount of awareness, the feeling of being alive, are proportional to the degree of oxygenation of the brain. Anatomically, the brain is favoured by a system of blood vessels. They are constructed and distributed to deliver the most copious supply possible of freshly oxygenated blood. The brain has three different sets of circulation. Each, in itself, is capable of maintaining the life of the cerebral cells. That shows how carefully Nature has provided a double margin of safety for the circulation of its most precious organ.

With consciousness, oxygen is consumed, carbon dioxide generated, and heat produced. An active brain has a higher temperature than an inactive one. A sleepy brain is actually colder than a wide-awake one. The heat liberated by consciousness is large. It is greater than can be accounted for from the combustion of carbohydrate and fat.

What the Brain Burns

There is evidence that the brain consumes sugar, since the blood returning from the brain contains less sugar than that going to it. It seems that the brain cells are burning something even more combustible than ordinary sugar or fat—the sulphur compound of phosphatid and cerebrosid. This fuel is an acid—lactic acid, the acid formed when milk sours. In sour milk it is formed from milk sugar, lactose. But the brain forms it either from galactose or glucose, the sugar of the blood.

It is one of the most interesting of the facts established by modern biochemistry that the brain has adapted itself to burn only the simplest of the carbon combustibles: lactic acid. Thereby the brain has made itself independent of variations in the amount of fat and protein in the blood. And also it has protected itself against disturbances due to some interruption of the series of changes involved in more complex chemical reactions such as those of muscle. The contrast between the complexity of muscle-energy metabolism and the simplicity of brain-energy metabolism is great enough to warrant some consideration of their details.

It was in 1907 that Fletcher and Hopkins discovered that lactic acid is produced and accumulated in muscle as it contracts. During relaxation, in the presence of oxygen, three-fourths of the lactic acid gradually is transformed into glycogen. It was then found by Meyerhof that glycogen, originating in the glucose of the blood brought to the muscle, is the original source of the lactic acid. Muscle reactions thus seemed to be a perfect example of the circular reaction: glucose → glycogen → glucose → lactic acid → glucose → glycogen.

This conception has recently been shown to be much too simple. The remarkable work of Lundsgaard, Meyerhof, and others have shown that the course of chemical events when a muscle moves may be outlined as follows:

(1) A compound of phosphoric acid and creatin, phosphocreatin (also called 'phosphogen'), breaks up into phosphoric acid and creatin. The muscle becomes more alkaline at the same time and contracts with the energy set free by the splitting of the substance. (2) A second phosphorus compound now comes into play, the triphosphate of adenosin. It cracks into phosphoric acid, inosinic acid, and ammonia, at the same time providing energy for the resynthesis of phosphocreatin. (3) The triphosphate of adenosin must in turn be resynthesized with energy which comes from the splitting of glycogen into lactic acid. (4) And the lactic acid in its turn is regenerated into glycogen by means of energy obtained from the oxidation of glucose.

This picture of what happens in mammalian muscles (and all behaviour is either muscular or glandular) shows how complicated its chemical reactions are. Also, why fatigue sets in so quickly with the accumulation of lactic acid, phos-

phoric acid, and the other by-products of the various steps involved. But it is seen that the ultimate source of the energy of muscle is the sugar of the blood brought to it. If not enough sugar is present, the muscle will then burn the fatty acid of fat.

Insulin, the internal secretion of the pancreas, is necessary for the burning of glucose by the muscles during contraction. It is also requisite for the synthesis of glycogen in both muscle and liver. In the presence of insulin, a compound of glucose and phosphate, a glucophosphate, burns to produce carbon dioxide, water, and phosphoric acid. If there is not enough insulin, as in diabetes, the muscle is always in danger of acidosis because of incomplete combustion.

Now, the structure and the chemistry of the brain have so evolved as to afford it the maximum of protection against the chemical accidents that may happen in muscle. Since 1929 a series of researches have proved that sugar is the sole fuel of the brain, the alternative utilization of fat and fatty acid not being available. Moreover, the brain continues to use the sugar of the blood as efficiently as ever, even in the absence of insulin. Studies made of the brain chemistry in animals whose pancreas has been removed have demonstrated that particularly important principle. Further, the brain does not store glycogen, glucose, or lactic acid. It depends upon the blood stream for its supply of them. But the brain does store the cerebrosids, compounds of galactose. And it has been recently demonstrated that galactose can be fairly well utilized even in the absence of insulin. It may be that the brain turns the glucose of the blood into galactose before using it.

Since the brain does not need insulin, it is clear that it does not live by burning sugar. What it does is to split one molecule of glucose or galactose into two molecules of lactic acid which it burns. The brain can subsist normally even in the absence of sugar if enough lactic acid is fed to it. But ordinarily it exists upon the glucose of the blood which it changes into its essential lactic acid. Lennox reported a research on human unanaesthetized patients which confirmed the isolated importance of sugar for the brain. He examined the chemistry of the brain and of the leg muscles at the same time. The muscles consumed fat almost exclusively, while the brain employed sugar alone for its

requirements. A study of the blood coming from the brain proved that it contained less glucose and less lactic acid than the blood entering the brain.

Not all substances are alike as regards the readiness with which they yield lactic acid. The substance, dioxyacetone, produces it more readily than any known sugar. Of the sugars proper, fruit sugar causes the greatest accumulation of lactic acid. And next in order comes cane sugar, probably because, when cane sugar is split, fruit sugar is formed. Glucose and galactose form the least amounts of lactic acid. The results are valid whether the sugars are given by mouth, by vein, or under the skin. Fruit sugar is readily changed into glycogen in the liver, and into lactic acid in the muscles, but not in the brain.

All these facts must be considered in any problem of nutrition of the brain. The brain gets its energy by splitting sugar (glycolysis) and burning lactic acid (oxidation). It thus has two ways of tapping energy, another example of its marvellous provision with factors of safety.

The Metabolism of Brain Work

During the Great War, Arnold Bennett made a note on 'Brains and Eating' which is still interesting:

> Brain workers expected no favours from Lord Rhondda: but they did not expect to be insulted. Says Lord Rhondda: 'Scientific opinion is unanimous to the effect that a man does not need any more food because he works with his brain than he would need if he were not working.' I should like Lord Rhondda to produce his authorities. I have little scientific knowledge of the mysteries of the human organism in being, but I have a very considerable empiric knowledge of the functioning of my own body. I assert that I can sit down fresh to my particular sort of brain work, and at the end of three hours' concentration upon it, I can be so utterly exhausted that further efficient work is impossible till the next day. I am prepared to believe that the exhaustion has a toxic origin, and that physical exercise will appreciably mitigate it: but, on the other hand, I should not have the volitional energy to take physical exercise in these circumstances until I had received nourishment, which nourishment I should certainly not have required had I remained idle or merely written letters or bright articles or memoranda for committees. My experience is that I need more food for a day's brain work than for a day of activity in the open air; that brain work induces

hunger, and that if this hunger is not satisfied, neuralgia ensues. And I know that my experience is quite a common one.

As one truly humble and anxious to learn, I beg to ask those who know more about me than I do myself the following questions: Does continuous and severe cerebration destroy tissue? If not, why am I hungry after working in a chair and not hungry after reading a novel in a chair? If it does not destroy tissue, what does it do? If it does destroy tissue, what becomes of Lord Rhondda's dictum?

Most people consider mental effort exhausting. Often keen brain work brings a feeling of turgidity in the head, as if there were more blood in it. So it has been assumed that mental activity must register some definite effect on the total metabolism.

The experiments of Benedict and others in this field are classic. They determined the basal metabolism of the subject. Then they allowed him to engage in various types of intellectual work. They expected to observe and measure the difference ascribable to the acceleration of metabolism by the work of the brain. But these yielded almost nothing. Intellectual activity, as distinguished from emotional reactions, involves almost no expenditure of energy. It is even possible to go so far as to say that the amount of energy used in a day's mental work is furnished by half a peanut.

Even if the brain did metabolize more during heightened activity, the necessary conditions of measuring the total oxygen consumption of the bodymind would explain the negative results.

Muscles are the tissues which contribute most to metabolism. In a full-grown man they constitute about 42 per cent (almost one-half) the weight of the body. The brain represents only about 2 to 3 per cent. Moreover, the brain, like the heart, is never completely at rest. Certain parts of the bodymind, the vital centres of breathing and heart regulation, are active even during sleep. But the muscles are relaxed during sleep, and it is their relaxation which constitutes the major factor in metabolism.

If the brain could be put absolutely at rest, the total change in oxygen consumption would only amount to 2 per cent. If the metabolism in the brain was increased by 50 per cent, only an increase of 1 per cent in the total metabolism would be registered. So the margin of error of total body-metabolism determinations is not less than 1 per cent. Thus, these negative experiments have not proved that the metabo-

lism of the brain does not increase during accelerated brain work.

But there are other researches involving not the oxygen consumption but the carbon-dioxide production. Becker and Olsen published their researches in 1914 and were confirmed by Chlopin and Okunowski. These indicate that brain metabolism is augmented as a result of intensive brain work. To quote :

> During the getting by heart of meaningless syllables, an increase of the organic elimination of carbon dioxide occurred, the main part of which was due to the psycho-physiological processes upon which the association work depends. The magnitude of this metabolic increase oscillates in a fashion parallel with the subjectively estimated amount of work performed. The increase will gradually diminish in amount according as the subject acquires greater practice in the work in question. The respiration of the subject resting, but awake, has a wavy course, but on entrance into sleep, the respiratory level is lowered and takes on a constant level value. The cause of the oscillations during waking time must partly be sought in changing states of consciousness.

It is possible that there is a rise in the metabolism on the day or days following intense intellectual work. All previous workers had concerned themselves with the metabolism during or immediately after the effort. This finding, if confirmed, would be most interesting. It would, then, appear that some product or products of the brain's activity act to stimulate those glands of internal secretion concerned with the control of metabolism. But, as yet, they have not been found in the blood or urine. They would also be valuable as a means of following the metabolism of the brain during its various activities. A method of ascertaining the effects, beneficial or injurious, of foods, drugs, experiences, and emotions would automatically be derived.

This postponed reaction of metabolism occurring after mental work reminds one of the specific dynamic reaction of protein in which the response may also be delayed. Much research work remains to be done. The control of the chemistry of the brain is perhaps the most tremendous problem in the realms of biochemistry.

The Vasomotors of the Brain

Foods may affect not the cells but the circulation of the brain. Not only does the brain become more gorged

with blood as a result of mental activity, but whatever and whenever the blood content of the brain increases, mental activity is stimulated. The first stimulating effects of alcohol upon brain are probably due to a dilatation of the brain's blood vessels. This is followed by a secondary toxic effect upon the brain substance itself.

Stimulation of the large sensory nerves tends to open the blood vessels of the brain. And that is why massage, involving the large nerve trunks, has an invigorating effect that is experienced almost immediately. But one of the most recent developments in this field has been the discovery that the substance histamine will produce a dilatation of the smallest blood vessels of the brain. In other words, this substance produces a flushing and increased pulsation of the brain which indicates engorgement with blood. Chemical studies have shown that following the injection of histamine the difference in oxygen content of the blood of the arteries of the brain, as compared with its veins, decreases, due to an increased flow of the blood through the brain. The veins contain more oxygen than they would ordinarily, because the increased speed of movement of blood through the brain carries more of the oxygen from the arteries into the veins. Mental work, like doing abstract problems, also causes a dilatation of the cerebral blood vessels.

Now, it happens that histamine is frequently formed in the intestine as a result of the bacterial decomposition of the amino-acid, histidine. Histidine is one of the absolutely essential amino-acids. It is contained in many foods. In many intestinal conditions, when acid-forming bacteria thrive in the colon and alkalis are absent, the histidine fails to be absorbed, but is transformed into histamine, as can be demonstrated by various tests. Certain individuals whose minds are preternaturally alert, who suffer from insomnia, but who have a low blood pressure and a poor energy reserve, becoming tired easily, have responded to treatment intended to eliminate histamine formation in the intestinal tract. There may be other foods and food products which affect the vasomotors of the brain and research will reveal them as important chemical clues to character traits or changes.

Brain Hormones

Steinach, collaborating with Kun in 1929, reported that he had been able to obtain from the grey matter a substance which stimulates the brain to greater activity. He called the substance ' centronervin '. Watery extracts of brain tissues contained a substance which stimulated reflex activity. An increase of from 400 to 600 per cent was observed in such performances as the attempts of injected frogs to catch flies in a closed chamber. Injected with extracts prepared from brain and spinal cords of rats, dogs, and human beings, these frogs exhibited a much greater agility in most activities.

The brain, therefore, generates self-stimulating substances as a result of its own activity. Now, there must be a dietetic supply of the raw materials of this substance. So the question is raised, What nervous tissue, such as brains, or foods, should be included in the daily diet when the complaint is a lack of urge to activity ? Also, whether foods rich in substances also present in the brain, such as copper, zinc, cholesterol, and the unsaturated fatty-acid-containing lecithins, be recommended in the diet of those who desire to mobilize a maximum of nervous energy in their daily work. One research by Schilf proved that injured brains of dogs could be brought to normal more quickly by including in their diet lipin extracts of brain tissue.

Certain phenomena of the action of Steinach's centronervin suggest a relation to a hormone of the pituitary (the prepituitary) gland. It may easily be that the after-rise in metabolism of mental work is a prepituitary effect. This and other findings indicate that the prepituitary is the gland of intellectual activity. The idea was first propounded and developed by Berman in 1921.

One other interesting related fact is that reported by Renald-Capart in his much-neglected paper, ' Contribution to the Study of Cerebral Metabolism '. His remarkable observation was that the liver elaborates a substance which is necessary for the brain to become conscious of pain. When the flow of blood from the liver to the brain is interrupted, operations may be performed without anaesthesia. If normal blood is injected into such an animal, sensitivity to pain is restored. Certain kinds of consciousness are dependent, then, upon the concentration of specific hormones in special

brain areas. That a chemical from the liver makes us sensitive to pain is as remarkable as the fact that morphine produces insensitivity to pain.

But the same principle might have been inferred from the established fact that consciousness is obsessed by sex when the internal secretion of the sex gland is sufficiently great and becomes concentrated in the sex centres of the brain. For it has been shown that the sex hormones of the sex glands are deposited in the brain and spinal cord. They charge the brain toward sex-directed activity. The contents of consciousness vary with the chemistry of the brain.

In this connexion, the experiments of Cushing are most interesting. He has shown how the direct introduction of glandular extracts, such as adrenalin or pituitrin, into the emotional centres of the brain will evoke emotional responses that are specific for the gland selected.

The Chemical Effects of the Emotions on the Brain

Hypodermic injections of post-pituitary extracts decrease the oxygen intake of rats. Cushing found the same effect as a result of injections of pituitrin into the brains of human beings whose heads had been operated on for one reason or another (with, of course, their consent and understanding of what was to be done). Pituitrin and its beta hormone also decrease the oxygen consumption of tissues like liver and testicle, even when they are growing in test-tubes, away from nervous control. Besides, the injection of pituitrin causes an increase in the lactic-acid content of the blood accompanying the diminished oxygen consumption.

Adrenalin may also produce an increased lactic-acid content of the blood by stimulating the brain to split more sugar rather than to burn lactic acid—glycolysis rather than oxidation. The brain then adds lactic acid to the blood rather than removing it.

An adrenalin or pituitrin effect, associated with strong emotional excitement, will have as a sequel a lactic-acid acidosis. This lactic-acid acidosis may explain the feeling of extreme fatigue or exhaustion following intense emotional episodes. The ingestion of large doses of glucose and bicarbonate of soda would tend to relieve the lactic-acid acidosis and so restore the sense of well-being. Such has been found to

be the case in many instances of emotionally exhaustible characters.

The Brain and the Vitamins

It is now evident that those craving intellectual activity are dependent upon the concentration in the highest centres of their brain of the *prepituitary, thyroid,* and *sex hormones.*

Tissues with a higher rate of metabolism live at the expense of those with a lower rate. Accordingly, the brain, as the tissue of the highest metabolism, resists starvation by maintaining its own weight and chemical composition, while the other organs are losing. In experimental animals, as well as in man, the growth of the brain during starvation is independent of the growth of the body as a whole. It proceeds to develop somewhat even when the body is continuing stationary in weight.

Stewart found that when his animals were maintained at body weight for sixteen days, the brain weight was about 125 per cent above normal. This shows how the brain under such conditions outstrips the other tissues. Jackson and Stewart, however, found that in the subsequent history of such animals the brain was injured, even though it grew continuously during malnutrition. This was proved by its failure to recuperate properly when optimal nutrition was provided. This demonstrates, up to the hilt, the importance of *continuity of proper nutrition for children,* no let-up being permissible.

In this connexion the fascinating researches of Maurer may be appropriately mentioned. Maurer studied the ability of two groups of rats to learn a maze. The test is as good as any of the intelligence of the rodents. One group was suckled by mothers who had a Vitamin-B-rich die. The other group was fed right from birth on milk provided by their mothers who were put on a Vitamin-B-poor diet. The Vitamin-B-fed group learned the maze in about fifty trials, while the Vitamin-B-poor group took about ninety trials—that is, almost twice as long to master the problem of the labyrinth they had to traverse in order to get to their food. These experiments suggest that Vitamin B is of the utmost importance during the first few weeks of life when the brain might be said to be growing furiously.

It also suggests the importance of full feeding of human

infants during the first week or few days of life, with a distinct derogation of the ancient practice of feeding a little sugar water, if the breast milk seems to disagree, or an adequate formula has not been found. Vitamin B should, at any rate, be added to the sugar-of-milk mixture, if no other effective measure can be found. It is quite possible that certain brains have been injured or made inferior by poor feeding during the first few weeks of life.

Now, the brain is exceedingly rich in Vitamin B complex. This has been shown to be a complex consisting of at least seven vitamins. There is B_1, an antidote for beri-beri. This is a disease of the nervous system in which, among other symptoms, the individual becomes paralysed. Another is Vitamin G or B_2 or P–P, which is pellagra preventive. Pellagra is a disease of the skin as well as of the nervous system. Sherman and his collaborators have proved that Vitamin G, or B_2, consists of at least two components, x and y. It is most interesting that the two vitamins, B_1 or F and B_2 or G, which are most closely associated with the integrity of the nervous system, should occur together.

True Vitamin B_1 deficiency causes the paralysis characteristic of beri-beri. In this disease degeneration of the peripheral nerves has often been asserted to occur. But as the most striking kind of improvement has been observed as soon as three hours after a dose of the vitamin has been administered, it is hard to imagine regeneration of injured nerves occurring so soon. As a matter of fact, the axis cylinders of the nerves have been described as uninjured. So the pathology really centres in the myelin sheaths of the nerves. As it is these myelin sheaths which minister over the reserve supply of nutrition for the nerves, the explanation might be that Vitamin B is somehow connected with the metabolism of the phosphatids and the cerebrosids in the nerves.

Richter, Vedder, and Clark have observed a disturbance of the cells and centres of the sympathetic nervous system in Vitamin B deficiency. A diet lacking in Vitamin B may be expected to produce a person with sympathetic-emotional instability. This should be looked for, when all other causes can be ruled out, and treated accordingly. It may be a contributing cause in certain cases of so-called neurasthenia, associated with glandular imbalance of the adrenals. Other diseases of the nervous system due to vitamin deficiency

other than pellagra may be caused by an insufficient supply of other components of the Vitamin B complex. The Vitamin B which protects the nervous system against beri-beri has been obtained in crystalline form by Windaus.

Pellagra is most probably due to deficiency of Vitamin G. It is a disease of both the skin and the brain. The association illustrates again the fact that the nervous system is really modified, specialized skin. The skin of the embryo is turned outside in and goes on to develop certain of the peculiar powers of excitation and transmission of energy, characteristic of the aboriginal outer covering of the lowest animals. How closely skin and grey matter resemble one another in chemical composition and dynamics is here made evident. For they are both still dependent upon the same substances for the preservation of their normality. Again, it is apparent that special tissues have specific food needs. They register the lack of a vitamin or other food material much sooner than other tissues because they have a particular affinity for them.

In pellagra the first symptoms and signs are those of the skin. It tends to get dry, roughened, and scaly. Then it appears chronically sunburned and inflamed. Then the mental symptoms supervene gradually as the patient deteriorates. Insanity finally occurs. Insane pellagrins have been described all over the world. It is the chief cause of mental disorder in certain countries, as, for example, in Egypt. The literature on the subject is enormous (see H. F. Harris's book on Pellagra).

The pioneer in the field was Lombroso. He described atrophy of the brain with fatty degeneration and pigmentation of its cells. For a long time pellagra was considered to be due to some form of protein (amino-acid) deficiency. Other factors may play a part, such as excessive exposure to sunlight and alcoholism. Jobling has long contended that it is due to infection of the intestinal tract by a fungus which produces a fluorescing substance that renders the skin peculiarly sensitive to ultra-violet rays. But it is now to be taken as fairly well proved that it is due to a deficiency of Vitamin G of the Vitamin B complex. The insanity of pellagra is also most interesting because it is the only form known which is due to a lack of minute quantities of a complex substance, Vitamin G.

The outstanding symptoms of the insanity of pellagra is

a peculiar slowing of the mental reactions. Otherwise the victim keeps quite immobile, answers questions slowly after long periods of saying nothing at all, in a low voice without inflexions. The trouble does not involve the emotions. It is far different from the depression of melancholia. It is an inertia, a lack of an internal stimulus to move about or react. Disturbance of the function of the stomach and intestine may be associated.

One of the most interesting recently discovered facts concerning pellagra has been reported by Walker and Wheeler, of the United States Public Health Service. It was observed, at the Milledgeville State Hospital of Milledgeville, Georgia, that a female epileptic, put on the ketogenic diet of high fat, low sugar, and protein, was much improved as regards her epilepsy, but developed pellagra. It occurred to Walker and Wheeler to put ten other adult female epileptics on a diet low in Vitamin G, but otherwise complete. They all showed signs of pellagra in a short time and their convulsive attacks of epilepsy were reduced by about 50 per cent. When Vitamin G was added to the diet to cure the pellagra, the epileptic seizures became as numerous as they were before the pellagra occurred. In other words, pellagra and epilepsy were shown to be antagonistic. Which is most interesting, since epilepsy is a disease of hyper-excitability of the brain cortex, while pellagra is a disease in which the sensitivity of the brain becomes much diminished.

There can be no doubt that Vitamin G is vitally necessary for the maintenance of the normal reactivity of the grey matter. A number of other factors may come into play before obvious pellagra appears in its absence or deficiency. Excess of carbohydrate in a diet predisposes to beri-beri, excess of fats to pellagra. Since each of these represents a disturbance of brain chemistry, it is evident how important the correct balancing of the requirements of the diet is for mental efficiency.

That the insanity of pellagra may be due to a deficiency of Vitamin G is as important a discovery as that the idiocy of cretinism is due to thyroid deficiency. The latter is caused by a lack of minute quantities of the hormone thyroxin. Both diseases show the dependence of the brain and the life of the soul upon a supply of traceable chemicals which can nowadays be prepared and controlled in the laboratory.

The chemistry of the brain functions will yield slowly but surely to an analysis of the relation of different food factors and endocrine secretions. The field is only just being opened to research, but it is bound to yield a harvest of the greatest value to mankind. The deliberate production of certified, chemically Grade A brains will then come into prospect. The foods containing adequate amounts of Vitamin G are meat, milk, yeast, liver, and eggs.

Other Special Brain Vitamins

Most recently, Pappenheimer and Goetsch reported some interesting experiments which point to the existence of a specific vitamin for the proper nutrition of the cerebellum. If these experiments turn out to be applicable to man, it will be a first demonstration that the different parts of the brain have unique needs in nutrition which will have to be taken into account in considering disturbances of character and personality. There are many other reasons for suspecting that the brain is not a single organ, but in itself an organism of many suborgans, each of which may demand special foods and vitamins in optimum amounts to function at their best.

Their experiments were as follows: They were studying the effects of various preparations of food containing Vitamin E, the anti-sterility vitamin. They found that if they used preparations relatively crude, as previously used by other investigators, the sterility was cured and the animal became normal. If the preparations containing Vitamin E were purified, the sterility was cured, but other symptoms indicating disturbance of the brain appeared.

They carried out their experiments on chicks which were raised on a synthetic diet consisting of skim-milk powder, casein, maize starch, lard, cod-liver oil, dried yeast, paper pulp, and a salt mixture. Another group of chicks was kept on a stock diet which maintained normal growth and remained well. Growth continued of the experimental group. But after three or four weeks the latter developed signs of trouble with their movements of co-ordination. They would get into a position of prostration, with eyelids drooping, legs outstretched, claws flexed, and head retracted and twisted. No true paralysis of the wings or legs was present at any stage of the condition which finally ended with somnolence and stupor.

Examination of the cerebellum showed spots of softening and haemorrhage. If animals cured of sterility by purified preparations of Vitamin E, who had developed this cerebellar disorder, were fed the crude preparations, they were also cured of their brain symptoms. The inference is that crude preparations of Vitamin E contain another substance necessary to the cerebellum which may be another vitamin. At any rate, this work marks the beginning of research into foods which are peculiarly necessary for the best functioning of the different parts of the brain.

The Outlook for Brain Perfection

The brain and nervous system of the human infant is the most immature and incompletely developed portion of the bodymind ushered into the world at birth. And the human being takes more time to evolve to maturity than any other member of the animal kingdom. This fact determines the whole course of social organization, since it makes imperative the provision of the maximum of safety and order for its development of some such institution as the family.

The immaturity of the brain at birth exposes it to special dangers, but it also provides remarkable and unique opportunities for its modification. For the younger an organ is, the more plastic and responsive is it to the demands put upon it before it attains maturation. The process of myelin formation, which accompanies learning of the environment, is a process of chemical change. As it proceeds, more and more proteins and lecithins are deposited in the brain, which make it heavier. The other nutrients, too, become more concentrated. All the evidence is strong that the activity of the brain, which is the activity of human culture, is associated with the highest metabolism and the most intense chemical reactions in the bodymind.

The study of the proper or ideal nourishment of the human brain is only just opening to the scientific view. Various converging lines of evidence demonstrate that the chemistry and functioning of the brain may be affected for better or for worse by food. It may never turn out that human brains are as susceptible to feeding as the larvae of bees, which, when fed on 'royal jelly', rich in fats, are transformed into queens, the fertile females of the species, but, when nourished on the ordinary bee-bread, become the female

workers which are sterile. But as a working hypothesis the following postulates may be laid down as the lines of advancement of the future:

1. The brain has its special nutritional needs and demands, necessary for its best development and functioning.

2. These chemical needs and demands may be satisfied in various degrees, ranging from the minimal to the optimal.

3. The chemical constitution of the brain, as well as the chemistry of the blood flowing through, to, and from the brain, are providing us with leads to the diet which will ideally serve the growth of its cells and their connexions during childhood.

4. Nevertheless, here, as elsewhere, individuality reigns paramount. The amount of calcium desirable for different brains, for instance, will vary with the under-activity or activity of the parathyroid. The brains of children suffering from tetany, due to defective parathyroids, contain less than the normal amount of calcium, which makes their reactions more impulsive and uncontrollable.

5. The human brain may be perfected by the control of diet sooner and more practically than by any of the other methods which have been proposed. Bigger and better brains is the objective of our study of the relation of the glands of internal secretion to food and character.

Man is what he is—the master of his planet—in virtue of the size, complexity, and plasticity of his nervous grey matter. But he has failed to become what he must become—the master of his fate and the captain of his soul. Under the stress and strain of his increasing numbers and multiplying inventions (his so-called civilizations and cultures), there appear deliriums, depressions, hysterias, which are proof of the inadequacy of his nervous system. They threaten his extinction in some colossal automatically achieved catastrophe, the veritable suicide of a species. Means must be found to build him stronger and finer ganglia for his consciousness.

The control of the chemistry of the brain is the hope of the human race. Against the clamours of the new-born machines and the irritations of the outworn mores, the sentient grey matter must be fortified by the regulation of its supplies of matter and energy. Then, and then only, may we be sure that man will enter into the great phase

of his self-determined evolution. How dependent the unbalanced bodymind is upon unbalanced diet and glandular co-ordination, a consideration of some of the recent discoveries concerning dementia praecox, manic-depressive insanity, menopause melancholia, epilepsy, and pellagra, as well as so-called nervous exhaustion or breakdown and fatigue psychosis, will make evident.

CHAPTER XIII

UNBALANCED DIETS AND UNBALANCED MINDS

PHILLIPPE PINEL made himself an immortal in the annals of psychiatry, as well as of all humane endeavour, when he first treated the inmates of the Salpétrière, the great insane asylum of Paris, as victims of illness and disease. Before him they had been handled as the accursed of Fate, worse than criminals. It was a revolution as notable in the history of mental hygiene as the contemporary French Revolution of 1789–92 was for the politics of France. The insane were hitherto kept in chains, maltreated as prisoners, and allowed to deteriorate until they died. It was Pinel who struck off their chains, practising the astounding doctrine that they were sick, and turned the prison-asylum into a hospital.

Pinel wrote : ' It seems that the primitive seat of insanity generally is in the region of the stomach and intestines, and it is from that centre that the disorder of the intelligence propagates itself as by a species of radiation.' Nobody believes that to-day, but it was an amazing novelty of viewpoint for his time. Substitute ' metabolism ' for ' stomach and intestines ' (and it is quite possible that that was what Pinel really meant) and the whole statement becomes quite modern. At any rate, modern clinical investigations have established that much insanity, much disturbed mentality, many psycho-neurotic symptoms, may be traced to disturbances of the metabolism of the brain, brought about by dietary deficiencies and imbalances, and their effects upon the endocrine glands.

Between Pinel, at the end of the eighteenth century, and Freud, at the beginning of the twentieth century, two great peaks of modern psychiatry, stretch the hundred years of the nineteenth century. The intervening valley presents only one other summit, the Munich psychiatrist, Kraeplin. Neither

Freud nor Kraeplin achieved progress in either developing or destroying Pinel's conceptions.

Kraeplin was a genius of classification. He separated out of the mess of symptoms called insanity, two groups. One was dementia praecox, later called ' schizophrenia ', characterized by a splitting, dilapidation, and finally complete disorganization of the personality, occurring in relatively young people. The other, manic-depressive insanity, is characterized by extreme fluctuations of moods and reactions in periods of excitement and depression, with intervals of apparent normality. He regarded these as distinct disease entities, with a peculiar life history and a predictable clinical course. He had some vague ideas about their relation to the glands of internal secretion, but could not go far with them because of the insufficient state of knowledge about the endocrines at his disposal.

Since then, and in our time, it has become established that both manic-depressive insanity and dementia praecox happen in individuals constitutionally predisposed to their misfortunes. The predisposition is affirmed by the hereditary history and the concomitant characteristics of the physique.

It has been shown that dementia praecox is associated with a profound disturbance of the endocrine glands which can be made to react favourably to treatment. Also, that the various phases of manic-depressive insanity, both the manic and the depressed cycles, are accompanied by definite signs of disturbance of the total metabolism. An imbalance of the thyroid-adrenal system in manic-depressives was suggested by Berman in 1921. A complete body of evidence converges to reinforce the view that insanity, and the disturbances of the bodymind which are the forerunners of insanity, are connected with affections of the endocrine glands and that their dietary precursors may be employed to assist in recovery of the normal mental state.

The Insane Traits of Civilization

The twentieth century, and particularly the last decade of it, has witnessed a great increase in the number of those afflicted with either dementia praecox or manic-depressive insanity. Our civilization, in fact, is a manic-depressive civilization. It alternates between attacks of maniacal over-production, over-exhilaration, and reckless spending of its

resources and then relapses into periods of depression when there is general underconsumption, deep-set, most melancholic of pessimism, and a contraction of personality which leads to a contraction of all activities. Our civilization might also be compared to dementia praecox in the lack of co-ordination of its various enterprises, and the suppression of the free expression of individual emotional life because of the suppressive demands of billion business and mass conformity.

Every panic on a stock exchange is followed by an increase of diabetes, thyroid diseases, manic-depressive attacks, and nervous breakdowns. Those who thus break down register in an exaggerated form the effects of the wear and tear of their daily emotional strains upon the millions who walk the streets of our cities. No wonder that among them are so many whose minds become so unbalanced that they commit all sorts of errors of observation, judgement, and behaviour, but not enough to draw attention to their chronically disturbed mental state. Thus, they plunge themselves into misery and unhappiness through unrecognized defects of their endocrines dependent upon the wrong food-supply.

Food affects emotional life through its effects upon the glands of internal secretion. Through the latter there is a constant play upon the brain and the sympathetic nervous system. A certain amount of control of the destructive and ugly emotions, fear, hate, anxiety, can be attained through the regulation of food. Nothing demonstrates the unity of bodymind more clearly than the concrete instances of phobias, anxiety neuroses, obsessions, and compulsions relieved by treatment of the endocrine glands.

Human beings cannot worry, cannot be anxious, do not feel afraid or angry or annoyed simply with their souls—they fear and react with all of themselves and with all of their organs. An acute imbalanced condition of bodymind occurs in the soldier who is about to meet the enemy, the man who has just lost his job with no prospect of another, the gangster who has to enter the room of electrocution, the banker who is informed of a run on his bank, the patient who is informed he has some incurable disease, the mother who realizes how desperately ill her child is. In all there is an acceleration of certain chemical reactions of the brain regulated by the thyroid, adrenal, parathyroid, and pituitary

glands. Their state of nutrition and stability may determine the difference between hysteria and equanimity.

Nature overdoes her reactions of defence and offence as she always exaggerates in all her activities. The Golden Rule of moderation is not her code. Overdoing means unbalancing, making difficult the restoration of balance. Excesses lead to exhaustion. So repeated excessive, chronic disturbances of the emotional life will result in pictures of exhaustion of the thyroid, adrenal, parathyroid, or pituitary glands. Anxiety or jealousy maintained over a protracted period of time may lead to the most profound disturbances of the chemistry of bodymind.

It has been during the last forty years that convincing evidence has accumulated of the dominance of the chemical drive in every emotional conflict which leads to neurosis and insanity. Contemporaneously, the personality and publications of Sigmund Freud have come to bestride the scene with the curious concepts and theories and all the phantasmagorical offspring of psycho-analysis. It began about 1880 with the now immortal young woman who lived in a little apartment in Vienna with her father. The story has been repeatedly told of how devotedly fond of him she was, nursing him through a chronic illness. One evening, fantasy entered the scene as she was drowsing in a chair, for she dreamed she saw a black snake emerge from a wall of the room to bite her father. In the next two years she herself became quite ill. Her illness presented a host of symptoms which were labelled hysteria by the medical diagnostician, who knew his business. There were transitory nauseas and coughs, passing paralyses and anaesthesias, confusions and deliriums, all sorts of phenomena, none of which could be traced to any organic defect of disease of the nervous system.

Freud, who had studied with Charcot at the Salpétrière in Paris, and was thus familiar with the then current wonders of hypnotism and hypnotic suggestion in curing hysteria, heard about her through his friend Breuer, a distinguished general practitioner of Vienna. He also heard how, by making the young woman talk about her symptoms while she was in the hypnotized state, Breuer had finally succeeded in relieving her of all her symptoms. Freud followed up the clue provided by this result. Developing the principles involved, he published with Breuer, in 1895, a

book reporting their clinical experiences and ideas, *Studies of Hysteria*. The book, now a classic, met with harsh criticism by the leading medical authorities of Vienna, and Breuer allowed himself to be intimidated out of his position. Freud himself continued his researches, and in 1900 published his *Interpretations of Dreams*. The birth of the nineteenth century may be regarded as the birth date of the psycho-analytic movement.

For the first fifteen years of its life the new movement had a stormy, fiery career, being attacked by the authoritarians of official medicine with every weapon of calumny, ridicule, and neglect. But it took over the whole field of mental illness and disturbance with the Great War of 1914–18. The young neurologists and psychiatrists in every nation found themselves with thousands of cases of ' shell-shock ', ' nerves ', and mental aberrations of various sorts on their hands. The tenets of psycho-analysis were the only complete set of doctrine available for mobilization in the emergency. They were almost universally pressed into service and adapted for the problems of the hysterias of war. But not without the most bitter opposition from the older generation of neurologists and psychiatrists.

Mercier's Criticism of Freud

One who may be mentioned as typical of those who fulminated most militantly against what he called ' Freud our Faker ' was the distinguished English psychiatrist, Charles Mercier. He was physician for mental diseases to the Charing Cross Hospital, London. The ' Freudian Fairy Tales ' aroused his sarcastic ire as much as the efforts of a previous generation of nerve specialists to ascribe every mental illness to latent syphilis or sexual excess.

To substantiate his virulent attacks, he put on record a number of cases of mental disease associated with peculiarities of diet and reacting favourably to a change of diet. In these patients the imbalance in the diet consisted mainly of an excess of starch, sugar, or fat, associated with a deficiency of meat. He obtained most remarkable results in these people by making them take meat and having them cut down their intake of fat, starch, and sugar.

Mercier pointed out that a positive association of an excess of fats or carbohydrates or deficiency of meat, in a diet with

mental disease, is not constant. The residents of the Arctic, who consume so much blubber, and the vegetarian denizens of the Equator, are not afflicted disproportionately by mental disease. As he wrote: 'That indulgence in fat which may be disastrous to the dweller in a temperate climate need not be anything but beneficial amid eternal ice and snow; and that abstinence from meat which may be fatal to an individual or a member of a race that is accustomed to a carnivorous diet may be innocuous to one who and whose ancestors have never tasted meat.'

While he noticed that a common symptom of excess of fat was headache, the outstanding accompaniment of meat deficiency was *confusion of mind.* In case after case in which the diet was subsequently found to be deficient in meat, the mental state is described in almost or quite the same terms: 'I feel muddled and dazed'; 'a wave of confusion comes over me'; 'I am so muddled about my work'; 'I have such confusion in my mind'; 'I feel half dazed and don't know what I am doing'; 'my mind is confused'; 'my head is in a muddle'; 'I cannot think'; 'I have a muddled feeling in my head'; 'I cannot apply my mind to anything'; 'I am half silly'; 'there is something in my head which causes everything to be jumbled up';—such were the chief complaints.

Depression was almost as common, and sometimes severe enough to lead to attempts at suicide. Defects of memory—forgetting to do things at the proper time—were striking in several cases, as were screaming fits and motiveless weeping and laughing in some of the women. Emphatically Mercier pointed out that he was not reporting these cases to prove that all mental illness was due to excess fat and sugar and deficient meat. What he maintained was that there were certain individuals who were predisposed to become mentally ill by a lack of meat when they took too much sugar and fat at the same time in their diet. Mercier realized that when he wrote 'lack of meat', he meant lack of protein, or, as it would be put nowadays, lack of amino-acids. There can be no doubt that some individuals may develop deficiencies of the ductless glands accompanied by mental symptoms in the absence of certain amino-acids or with a low total intake of amino-acids.

The Behaviour of War Malnourished Children

While Blanton was with the Army of Occupation in Trier, Germany, he collected a number of significant observations on the relation of malnutrition to mental and nervous conditions in children. He studied sixty-five hundred school-children between five and a half and fourteen years of age. At least 40 per cent, he found, suffered from war malnutrition to an extent sufficient to cause a loss of nervous energy.

In general, the children were listless, apathetic, sat about without energy, and did not break into activity spontaneously as normal children do. The children who played became tired too quickly. They could no longer go on long walks as they used to because of their fatigability. There was physical evidence of debility.

In addition, a definite lowering of the whole standard of school work was apparent. Half the children, who in pre-war times did superior work, now did only average work. The number of children doing inferior work increased from 20 to 30 per cent. What was even more striking was the great increment in children afflicted with poor, lisping, slurring speech. It was a condition of the brain due to retardation of, or interference with, the fine co-ordinations necessary for good articulation. There was no increase of the speech disorders which occur in adequately nourished children, such as stuttering. Nor was there an increase of similar psychic disturbances, such as tics, neuroses, or psychoses.

The intelligence of the superior children was not affected. But among the border-line types—who form the majority in all populations—there was a rise in the number of mental defectives. The percentage of children failing to pass their grades was augmented from 8 per cent to 15 per cent. This group was dull and apathetic and obviously stupid.

Among the other specific changes noted in children as caused by malnutrition, he listed the following:

1. Lack of nervous and physical energy. So easily fatigued mentally and physically that they would often fall asleep in school.

2. Inattention—inability to concentrate. It was difficult to have them keep their minds on any subject for more than a few minutes at a time.

3. Poor and slow comprehension. The children found it difficult to follow explanations. As one teacher said, 'It takes the children longer to think.'

4. Poor memory. The children needed thirty minutes to memorize a few lines which could be done in half the time. It seemed impossible to make them remember anything they learned in arithmetic.

5. Restlessness and irritability. The children could not sit still; they either wanted to talk, giggle, or whisper, and it was difficult to keep the classes disciplined.

Now, all of these are definite personality and character changes which could be traced to the prolonged action of a diet poor in proteins, fats, mineral salts, and vitamins. It is impossible to say just what part the special deficiencies played in the genesis of the whole pathetic picture. All probably contributed to the total effect upon the endocrine glands, the brain and the rest of the nervous system.

Malnutrition affects the Ductless Glands

Holt, whose book on the *Care and Feeding of Children* was the nutritional Bible of so many mothers of the last generation, recognized that malnutrition led to character disturbances in children. He divided abnormal children who were both underweight and nervous into two classes. Of them he wrote:

> One is the dull, listless type, not infrequently considered subnormal mentally, lacking in energy and ambition, easily fatigued, disinclined to exertion, with poorly developed muscles and flabby tissues; the other type, ambitious, often excitable, usually hard to manage, energetic, in fact overactive, never still, sleepless, frequently with good muscular development, but almost no subcutaneous fat.

These two types may be and should be correlated with the reaction of the adrenal glands and the thyroid glands to malnutrition. The apathetic malnourished children are the adrenal deficient. The hyperactive are the hyperthyroid. They can be distinguished by various tests of glandular function, clinical and laboratory, which may be made. And their response to treatment of the ductless glands is the best and most convincing proof of their importance in understanding and handling these malnourished, often misunderstood and mishandled, children.

Lydia Roberts has had a large experience in studying

malnutrition in children. She has proposed a view concerning the effects of malnutrition upon the brain and nervous system of children which is consistent with the ideas advanced in the preceding chapter on the chemistry of the brain. She has summarized her ideas as follows:

> The rapidly developing brain and nervous systems of the child require certain essential food materials for normal growth. Moreover, the nerves need a moderate covering of fat to protect them from external stimulation. In a malnourished child, both of these conditions for a normal nervous system are apt to be lacking, the food materials more than likely being deficient and the nerves unprotected owing to the lack of subcutaneous fat.

It is probable that it is not so much the lack of fat beneath the skin as much as the lack of phosphorized fats and unsaturated fatty acids and sterols for the brain and the endocrines which should be held responsible for the nervousness of these children.

Weir Mitchell was one of the first to implicate a disturbance of the metabolism of fats in 'nervousness'. In his monograph on *Blood and Fat*, published in 1891, he expounded his method of treating neurasthenia and nervous exhaustion by means of diets high in fat. He realized how activity tended to increase malnutrition and so forced his patients to rest in bed and fed them high-fat food seven to eight times a day. By his therapeutic results he was able to prove empirically that nervous malnutrition could cause serious disablement of the whole personality.

More recently, the Sehams have produced interesting confirmations of Weir Mitchell's theories and methods. A clinical study was made by them of the relation of malnutrition to nervousness and fatigability in children. They reported that, in general, malnourished children tended to be hyperactive, setting up a vicious circle of hyperactivity increasing the malnutrition, in turn augmenting the activity. Such children were definitely more nervous and irritable when undernourished than when their nutrition was improved by appropriate measures. Although previously described by their teachers as 'nervous', 'excitable', 'lacking strength and stamina', 'tiring quickly', 'looking pinched', these symptoms were relieved when a régime of relaxation was combined with proper feeding.

The Sehams also carried out complementary experiments

on malnourished rats, and found similarly that such rats were hyperactive, irritable, and restless. They counted the number of times the rats blinked their eyes in a given time as an indicator of their nervous irritability. It was found that blinking was much more pronounced in the malnourished, a tendency which ceased as soon as the rats were properly fed. It is interesting in this connexion that Plummer and others have emphasized excessive blinking as an early sign of overaction of the thyroid gland.

In a series of articles, Cramer stressed the importance of vitamin underfeeding in the production of mental inferiority in children. He suggested that certain ' repeaters ' of school grades, those who fail to be promoted at the end of the school term and have to repeat their courses, are the results of vitamin starvation. It is worth noting that the only symptoms of a latent scurvy, due to deficiency of Vitamin C, may be listlessness and laziness, combined with a certain depressed irritability. Arctic explorers have been struck by this combination of quarrelsomeness with lassitude as the earliest character manifestations of scurvy.

It was the James Lind, surgeon in the British Navy during the middle of the eighteenth century, whose dietetic experiments with sailors corroborated the findings of Kramer, who also made the first clinical observations of the effect of scurvy on behaviour. Following up the assertions of Kramer as a result of his experiences during the war between the Holy Roman Empire and the Turks, that dried vegetables and fruits would not prevent or cure scurvy, but that fresh vegetables and fruits would, Lind favoured lemon-juice syrup as part of the regular ration of all sailors, and showed how it helped the mental as well as the physical symptoms of the disease. Apropos of the psychological effects of scurvy, Lind wrote :

> An uncommon degree of sloth and laziness which constantly accompanies this evil [scurvy] is often mistaken for the wilful effect of the patient's disposition. This may prove fatal to many, some of whom, when obliged by their officers to climb up the shrouds, have been seen to expire and fall down from the top of the mast.

Almost two hundred years later, Sir Frederick Gowland Hopkins put upon record the history of an unconsciously-carried-out experiment of the effect of a similar food deficiency

on behaviour in an English preparatory school. During the winter terms it was noticed that some change had come over the boys so that their work and general deportment became 'vaguely unsatisfactory'. In their play, too, they showed much less energy and there was a general display of listlessness and irritability. A number of lesser disturbances of health seemed to appear almost epidemically. But though the drains were studied and flooded, throats examined for infection, and other investigations made, nothing appeared as an explanation, and the boys grew worse in every way. Finally, the diet was thought of as something to look into. The daily food was shown to be all cooked, with nothing raw. This had long been the usage of the school's cuisine. But the boys had been accustomed to buy fresh fruit at a neighbouring shop with their pocket pennies and had thus instinctively protected themselves against scurvy. For some reason the shop-owner gave up business and no one replaced him. An epidemic of the first phase of scurvy, with its marked psychological symptoms, had followed. Raw vegetables and fresh fruit were made a regular part of the menu and the boys were cured of their laziness, lassitude, and irritability, the trio Lind had described as characteristic of his sailors suffering from mild scurvy. It is interesting that these symptoms are also the earliest indications of an adrenal-gland insufficiency, pointing once again to a relationship between Vitamin C, hexuronic acid, which is found in the cortex of the adrenals, and the manufacture of the cortical hormone.

The Chemical Chassis of Psychology

All these observations upon the direct relation between food intake and disturbances of character provide material for the youngest branch of chemistry to-day—the science of psycho-chemistry. Psycho-chemistry may be defined as the science which deals with the chemical foundations of psychology. As such, it is bound to become the basis of whatever will be scientifically known about psychology. Its developments will provide knowledge and methods of control of behaviour undreamed of in the older psychologies.

The psycho-chemist will give humanity the secrets of the chemistry of its soul. What the human race will do with them or attain by means of them, no one can prophesy. But already he has invaded the great territory of the unbalanced

bodymind known as insanity. All the provinces of the great territories of madness, dementia praecox, involution melancholia, manic-depressive psychosis, epilepsy, compulsion neuroses, are being trenched by the explorations of the biochemist-psychologist. The borderland of mind and matter, hitherto a No Man's Land of Science, is being cleared and claimed by those who combine the training and interest in both fields that make it possible for them to function better than the specialists. And enough has been made apparent by their efforts to present a vista of the triumphs of therapeutics burgeoning in the womb of time.

The Need for Oxygen and Water

The science of psycho-chemistry must begin with the profound need for oxygen of the brain cells. Chiefly this is because they, as the leaders and pacemakers of the bodymind, have the highest rate of metabolism. Merely to keep alive, these cells need and use more oxygen per minute than any others. An insufficient supply of oxygen for one or two minutes produces a loss of consciousness because these cells fail to function. An absence of oxygen for six minutes will create irretrievable changes in them, so that no recovery is possible. And death ensues for the entire organism and personality.

The metabolism of brain tissue has been studied in the test-tube. Grey matter has been finely comminuted and its oxygen consumption measured in a thermostat. It withdraws from the surrounding atmosphere more than its own volume of oxygen per hour. This is much more than any other tissue can do. Warburg, the pioneer student of these matters, has arranged a table of the metabolic hierarchy of the different tissues, with brain at the top and connective tissue at the bottom.

It has been mentioned that the brain feeds upon lactic acid derived from glucose. Oxygen and lactic acid burn to make that inner fire which is the soul. Thus, oxygen and glucose of the blood are the two great brain foods. A constant supply of them is necessary for its activities. Necessary for this combustion of the brain are various enzymes which assist oxidation. These, oxidases, have been found, as also iron, which Warburg has shown to be so important as a carrier of oxygen. Iron and traces of other metals also

function most importantly as catalysts in handing on oxygen from blood to brain cells and within the brain cells. Freeman has reported a deficiency of what he calls 'catalytic' iron in dementia praecox. All the facts obtained point to the existence of most elaborate arrangements for maintenance and security of the oxygen supply of the brain.

A great deal of evidence has accumulated that there is an oxygen difficulty of the brain in dementia praecox. Inextricably intertwined with it is the important problem of the relation of oxidation of the bodymind as a whole to brain oxidation. Since the brain cells are burning at the highest possible rate, they will react to a lowering of the general metabolism sooner than the cells of any other organ. So that a metabolism which may be sufficient for the other cells may be definitely subnormal for an active brain.

Thus, in heart disease, when there is partial failure of the circulation, so that not enough oxygen-laden blood passes through the brain per minute, delusions and hallucinations may be the earliest symptom of a failing circulation. These delusions and hallucinations may present themselves to people who are profoundly anaemic or who are suffering from partial suffocation, such as occurs in carbon-monoxide poisoning. All these are disturbances of oxygen insufficiency. In mountain sickness or aeroplane sickness, similar upsetting of brain action may develop in susceptible individuals exposed to the rarer oxygen of the upper atmospheres. On the other hand, supplying an excess of oxygen to the brain, such as is done for caisson workers, generates a feeling of well-being and exhilaration which may be described as 'oxygen drunkenness'. The brain oscillates between being oxygen-starved (depression) or oxygen-surfeited or intoxicated (exaltation).

The Disturbance of Bodymind in Dementia Praecox

Dementia praecox is one of those diseases in which the whole bodymind problem, the relation of the mind to the body and of the body to the mind, is most sharply focused. It is a disease of young people which has probably existed as long as the responsibilities, duties, and taboos of group life have been evolving. And that, according to the latest estimates of the archaeologists, is at least for about six thousand years. But it was only as long ago as 1672 that Willis, an English pathologist, described the symptoms of disin-

tegration of the personality occurring in young people as a medical entity. The founder of modern clinical medicine, Sydenham, with his fine feeling for species of diseases, catalogued the characteristics of what he called 'stupor' or 'stupidity' of the young. In the nineteenth century the Scotch psychiatrist, Clouston, narrated the phenomena of what he called 'adolescent insanity'. But it was that genius of classification, Kraeplin, who first typed it as both an affection of the emotional life and a disorder of metabolism.

Dementia praecox is a morbid reaction of a delayed and prolonged puberty and adolescence. It is *the* disease of initiation of the personality from the infantile world into the adult world, the world of duties and accountabilities, opportunities and restrictions. Concomitantly with the changes in his physique which parallel the growth and functioning of the organs of the sex apparatus, the individual is forced to revise his whole set of values and attitudes toward reality. He is, in effect, told by his bodymind, as well as by society, 'to put away childish things' and turn to the objects worthy of a man. But sometimes he cannot and therefore will not.

The adolescent metamorphosis of the personality is normally associated with a great stress and strain of the bodymind. A fundamental shift occurs in all the balances of the bodymind, but in particular among those of the endocrine glands. Even the fairly well-constructed individual is transformed during the period. But it is a time of testing for any and every weakness of the bodymind's construction.

Certain individuals, characterized often by a special type of physique, and frequently by a certain sort of heredity, may show even during their childhood the signs and symptoms of those who are to become 'stranded on the rock of puberty'. Such children do not seem sufficiently interested in their environment, and prefer withdrawal from contact with it. Nor do they develop the relations of *en rapport* with other children. These children have been designated as possessors of the 'shut-in' type of personality. As they become pubescent, in their teens, oddities and peculiarities of mental reaction and general behaviour begin more and more to manifest themselves. After a time, sometimes not until the late twenties or even thirties, the abnormalities of conduct change quite definitely into the stigmata of insanity.

Various forms of the disease present themselves in accord-

ance with the endocrine formula of the individual. In one, the simplest form, he acts as if he were living in a dream. The outside world seems to have no meaning or interest for him. When confronted with demands from the environment, there is evasion with a reaction of sudden silly paroxysms of laughter. Deterioration of the personality sets in, so that the slovenly appearance, the inappropriate emotions or lack of emotion, and the whole picture of the disease finally emerge. Sometimes the condition may be arrested at one stage or another of its incubation. In certain phases of its evolution, the hobo, tramp, and vagrant personalities are varieties of its crystallization.

One type of dementia praecox of particular interest to the psycho-chemist, early recognized because of its characteristic external manifestations, is that known as 'catatonia'. Stuporous or anaesthetic states alternate with phases of excited activity. Peculiar fixed positions are assumed. Mutely the catatonic will maintain his odd attitude or grimacing for days. In the excitement period there may be impulses to suicide or homicide in association with delusions and hallucinations.

How intimately related chemical conditions of the brain are to these manifestations of catatonia has recently been proved by the experiments of Solomon, Kaufman, and D'Elseaux. Under the influence of a mixture of carbon dioxide and oxygen three to five times as great as that of the atmosphere, catatonics have been temporarily removed from their insane state. Putting them into a deep sleep with sodium amytal has accomplished the same effect. A catatonic patient, placed by Freeman in a compression chamber in which the oxygen was of a concentration six or eight times as great as that of the atmosphere, stopped throwing himself about, talked a little, and wrote answers to questions. It is in catatonia that the greatest deficiency of catalytic iron in the deepest layers of the frontal lobes of the brain has been found.

Not only are there these chemical facts about catatonia, but it may actually be induced by the administration of the drug bulbocapnine, which acts upon the grey matter of the brain. A definite picture has been evolved of a chemical causation and a possible chemical treatment of this particular form of dementia praecox. Nor is this all that has been learned chemically about schizophrenia.

There are other forms of dementia praecox, such as hebe-

phrenia and paranoia. In hebephrenia there is often an acute onset. Delusions and hallucinations, particularly of hearing, are apt to be present from the beginning. Accusing voices accompany the rapid dilapidation of the personality. In the paranoid variety, the individual reacts to his own breakdown in the face of a too strong environment by building within himself a system of delusion and grandeur, which, no matter how absurd and fantastic in itself, makes him out to be really the superior in the face of difficult and threatening situations. All these are interesting and informative because they throw light upon the defence mechanisms by which an individual attempts to protect himself against his own inadequacies.

Many attempts have been made to treat dementia praecox by psychological methods. Particularly has the technique of psycho-analysis been invoked in the endeavour to unravel the mystery of the disease. Jung has busied himself especially with the matter of buried complexes as indicating tendencies of regression into the infantile state. And much interesting information has been obtained. Additional insight into the mechanism of personality formation, in its psychic facets, has been collected. But no genuine restitution of the shattered personality has ever been achieved by psycho-analytic methods, at least to the satisfaction of critical and sceptical observers and students in the field.

On the other side, many have sought to explain this most devastating disease of the transition from childhood to maturity on the basis of brain pathology. As in the case of epilepsy, eyes have been directed to the grey matter, with the hope of discovering definite defects in the gross structure of the brain. Josephy reported fatty degeneration and sclerosis of the ganglion cells in the third and fifth layers of the frontal and temporal lobes of the brain. Though these have been reported, they have not assuaged the scientific instinct of curiosity concerning the causation of the disease. For it does not provide a concept of origin which would enable the physician to control the course of its development, or reverse the morbid process.

There is only one true test of knowledge of a disease—it is that conception of it which makes it possible both to prevent it and to abbreviate it. The physician then makes use of the natural healing powers revealed by such knowledge

to correct and restore the condition of balanced integration which is health. Most recent work with this ideal in view has pointed with greater and greater emphasis to a deficiency of oxygenation in the nervous system as the important underlying difficulty in dementia praecox or schizophrenia. Careful studies of the basal metabolism have revealed a greater tendency to a lowering of oxygen consumption and carbon-dioxide production. The chemistry of the nitrogen compounds as well as of the sugars and starches is disturbed. There is a failure to attain the normal when tests of stability of the metabolism are applied. The acid-alkali balance is subnormal, the blood being more acid than it should be, and resembling the status of the sleeping normal person.

Thus, the schizophrene who seems to be passing his life in a dream—in a dream from which he does not wish to be awakened—reflects in the chemistry of his blood the state of his bodymind. Carbon dioxide as carbonic acid seems to accumulate in the blood and tissues because the respiratory centre, normally so sensitive to the slightest change of the acid equilibriums in the blood, has become relatively insensitive. Even when the carbon dioxide in the inspired air is increased by as much as 2 per cent, there is no increase in the rate or amplitude of breathing, as would normally occur as a reaction of ventilation.

As he breathes in and out while he rests or indulges in the peculiar manifestations of his disease, the carbon-dioxide concentration of the air is definitely higher than in the normal. And the alkaline tide in the blood and urine after meals—expression of the withdrawal of acid for the gastric juice—does not happen. All point to the existence of a fundamental metabolic disorder implicating the ability of the brain cells to use oxygen, much like that which forces the normal individual to seek sleep for recuperation. Only, the normal repair process which enables him to arise refreshed after a certain period is not working in the case of dementia praecox, and so he persists in his dream state.

Dementia Praecox as a Deficiency Disease

Altogether, the available evidence substantiates the conception that dementia praecox is a disease of failure to mature sexually psychically. The ripening, by which the process, Boy-into-Man and Girl-into-Woman, is carried to completion,

is arrested. Literally, a breakdown of the personality's organization occurs. The environment overwhelms him or her who is destined to undergo an arrested development of those progressive metamorphoses which usher the individual into the capacities of manhood and womanhood.

Now, tracing the reasons for this failure of development, defects of both substance and function come to be seen as fundamental motifs in the story. A triple deficiency occurs. There is a lack of a sufficiency of certain food elements. These both produce and influence for the worse a weakness and inadequacy of certain of the glands of internal secretions. The evil effects of these deficiencies of food essentials and hormones favour a constrictive environment with a consequent starvation or distortion of character. All these contribute to evolve a pattern of personality which retreats into, as it were, a cocoon state, before the threatening pressures, the novel stimuli, and the need for expansion in the whole range of his activities that maturation brings.

Analysis by Berman of the diet of a series of schizophrenics who have come under his care has revealed patent imbalances and deficiencies in the panels of food, hormones, and environment extending over a long period of time prior to puberty. Defects of the diet have been important, not so much in the field of the caloric intake and the caloric foods—the sugars, fats, and proteins—as in the region of the minerals and vitamins. These latter, especially those present in raw and unmanipulated foods, are the ones most closely implicated in the proper nutrition of the ductless glands. If they, the organs of chemical control, are subnormal as a matter of heredity, or as a result of injury, by infectious disease (such as diphtheria, grippe, or scarlet fever), slight insufficiencies of the rarer minutiae of nutrition over a longer period of time will take them over the line separating latent from manifest disease and breakdown.

In a favourable environment, or one, at any rate, not hostile or aggressive, these children may manage to pass the ordeal of adolescence without becoming insane. The adjustment to the entry of the sex glands into their lives does transpire, and they become the dull normals who take most readily to the conventional routine of the local mores. They are the supermorons who form the bulk of the populations of most civilizations.

But it is when the environment suddenly changes from comfort and ease into a series of hostile overwhelming pressures that the predisposed may develop the 'breakdowns' which may be the forerunners of dementia praecox. These nervous breakdowns generally tend to repair themselves, and sometimes the recuperation is permanent. Yet they have a tendency to recurrence, with the goal of complete disorganization and retirement from the environment, which is insanity, always in prospect.

In the case of the adolescent or post-adolescent who develops dementia praecox, it will nearly always be found that the environment has not been a mould but a vice for the individual. There has been a cramping and crippling of the child's centrifugal activities, by the parents especially. Always with the best intentions, of course, the personality has been driven in upon itself by the inhibitions and checks of the social controls to which he has been subjected. Confronted with the demand to grow, the stunted, crippled, malnourished soul responds with a negative tropism. Such withdrawals, aversions, evasions and introversions are most marked in the face of the invitations and challenges of sex in particular as well as social opportunities in general.

How to break up this vicious circle of deficiencies of substance and function, of food, the endocrines, and character, is the problem for the therapist. A change of environment is possible, accompanied by the conversational analysis which may confer insight into the process of flight into the dream-state. It is easy enough to make clear to the individual the reasons for his refuge in narcosis. Rationally he may be assisted to understand his resort to a condition which is anodyne for this tortured soul. But this is usually ineffective because his unconscious emotions know only too well that his constitutional weaknesses are not remedied by merely verbal explanation. And most often it is too late. The sufferer is no longer accessible to the rules and motivations of healthy reason. His logical faculty has drowned in the sea of oblivion into which he has plunged for his spiritual suicide.

As a practical matter, then, the physician's attention is compelled to concentrate upon what may be achieved by the correction of the errors of food habits, and an attack upon the defects of the ductless glands. Almost nothing in any large systematic way has been attempted in the way of

influencing the suboxidations in the brain by special foods. But certain striking results have been attained by treatment intended to correct and aid the endocrine organs. Their debility has been successfully attacked with the most astounding and sometimes miraculous results.

Kraeplin was one of the first to endeavour to influence the course of the malady by glandular preparations. He confessed failure, probably because he worked with impotent extracts and dosages. Soon his assertions could be contrasted with those of Wagner-Jauregg, who reported that the administration of thyroid and gonad medicaments produced markedly beneficial effects upon the first stages of hebephrenia, the commonest form of the affection. If the glandular extracts were potent enough to accelerate the more definite appearance of the secondary-sex characteristics, the symptoms of insanity tended to disappear at the same time. Then a gradual restoration to normal of the disturbed bodymind sometimes followed. These were the earliest reports of effective glandular treatment of dementia praecox.

In 1921, Lewis and Davies described experiences with a series of twenty-two dementia praecox patients treated with thyroid, pituitary, adrenal, and gonad extracts. Two of them were given no treatment at all. Of the twenty treated, all responded with some signs of improvement, as agreed by six impartial physicians. Four were discharged as 'cured', and nine were so much improved mentally as to provoke the special comment of the observers.

All this was accomplished more than ten years ago when glandular preparations were by no means as powerful or standardized as those now available. All over the world since, isolated instances of successful treatment of dementia praecox by glandular preparations have been published, until to-day a formidable array of evidence favourable to the treatment presents itself. In certain individuals, the therapy has been supplemented by a psycho-analysis. The preceding endocrine therapy made it possible for the individual to partake of the analysis and to benefit by it. This undoubtedly will be the ideal method of choice in the treatment of patients in the future.

A striking case of the results of glandular treatment has been cited by Sawkins, of the Kemmon Mental Hospital in New South Wales. This man, more than fifty years old,

had been in the hospital for twenty years. Difficult to handle and annoying to the extreme, indulging in thieveries of all sorts, he made himself an all-around nuisance. He had the general characteristic symptoms and stigmata of dementia praecox. He was put upon large doses of thyroid. As he came under the influence of the treatment, there was a remarkable increase in his vitality, undefinable but definite. His conversation became rational and a sense of social conscientiousness appeared, so that he dropped his old mischievous tricks. He was finally discharged and proved himself able to carry on the duties of a job by which he supported himself.

These reports of cures of isolated instances of dementia praecox are now being succeeded by recordings of similar results in a whole series. Hoskins and Sleeper, for instance, have presented the details of a number of individuals long suffering with the various manifestations of schizophrenia whom they have restored to social and economic life by the administration of very large doses of thyroxin. Particularly have they emphasized the necessity of prescribing amounts far above the conventional limits. In a personally observed series of early cases, Berman found that a combination of thyroid and thyroxin in the extreme doses was effective in awakening the patients out of the spell of deep sleep into which they had sunk.

Dementia Praecox resembles Hibernation

Awakening—the substance of brain awakening: that is the name for thyroxin which these instances of its effects suggest. And interestingly enough, that is what the word hormone means—an awakener or an excitant of function. In that sense, thyroxin, working in conjunction with Vitamins B, C, and G, is the dominant hormone of the nervous system.

The awakening action of thyroxin suggests an interesting and fruitful comparison with the phenomena of hibernation seen in certain of the lower animals. A hibernating animal is one whose ductless glands become inadequate in a cold climate. They cannot maintain the processes of metabolism during the winter or periods of low temperature. Consequently, the temperature of the animal becomes lowered below the point of wakefulness, and the animal goes to sleep. Then, with the arrival of warmer weather, the requirements

of metabolism are met by the ductless glands. The animal awakens and again becomes active. Instead of sleeping for a night, the animal has lain dormant for a season.

Microscopic examination has shown that the ductless glands of a hibernating animal are in a state of quiescence. Their cells present the evidence of a lowered production of their secretions. If a sufficiently potent glandular extract, such as thyroxin, is injected into a hibernating animal, even in mid-winter, the animal awakens. At the same time the temperature rises and the creature resumes activity.

Now, ultra-violet rays are a stimulant to the ductless gland system. Combined with the rising temperature, they effect the resurrection of spring in the hibernators. There is a renaissance of the endocrines. A resumption of the manifestations of life follows.

In these naturally hibernating living beings, the whole process has become physiological. It is an adaptation to the cycle of the seasons. The glands degenerate and regenerate in accordance with the movements of the earth in its orbit in relation to the sun. A balance has been established between the ecliptic of the planet and the normal rhythms of the organism.

Dementia praecox may be regarded as a state of hibernation assumed by a human being when his ductless glands become inefficient in the face of a freezing spiritual climate. A cold world drives the sufferer back into a sort of walking sleep, in which he can dream a sweeter, warmer life, one more moulded to his heart's desire, which is that of a child. That upon examination so many of those afflicted with dementia praecox show the physical stigmata of infantilism and of retarded sexual development is thoroughly consistent with the conceptions of defective metabolism, dependent upon abnormal endocrines. As a defence reaction, a state of body-mind analogous to that of hibernation slides the individual into his dementia. The action of thyroid upon the praecox resembles its effect upon the hibernator. According to Carter, a variation in the amount of thyroxin in the blood plays a part in the production of daily sleep in the normal.

The Chemistry of Manic-Depressive Insanity

Another disease of insanity which is being intensively studied in the last few years by modern chemical methods is

manic-depressive psychosis. Dementia praecox is an insanity of adolescents and post-adolescents, of the period intervening between childhood and maturity and occurring mainly in individuals who have never become really adult. Manic-depressive psychosis is an affection of the bodymind typically manifesting itself in those who have attained maturation. It makes its appearance most often during the late thirties, forties, and fifties. And so it represents an altogether different variety of life-reaction. It, too, however, is associated with, and apparently dependent upon, a special predisposition of certain of the ductless glands.

Manic-depressive insanity is characterized by the violence of the manias or depressions which are its most outstanding phenomena. In its most typical form, the individual alternates between a phase of mania, acute irrational excitement, volubility and activity, and a phase of melancholia, deepest unreasonable depression, taciturnity and immobility. The manic acts as if he were drunk ; the depressive as if he were under the influence of some narcotic drug. Because their attacks of mania and depression tend to recur in cycles, these people have also been named ' cycloids ', and the disease has also been called ' cyclic insanity '.

Certain observations have accumulated which point to chemical origins for manic-depressive insanity. In other words, there is ever strengthening evidence that it is not simply a ' psychic ' disturbance, but an upheaval of the personality rooted in an abnormal chemistry. Once again the unity of bodymind becomes emphasized in more manifestations of it in the domain so long regarded as the abode of the soul alone—the terrain of the mysteries and maladies known as insanity.

It has long been asserted that manic-depressive psychosis tends to recur in diabetic families. Then studies of the afflicted have demonstrated the presence of abnormalities of sugar tolerance, pointing to an imbalance between the glands which control sugar metabolism, such as the adrenals and the pancreas. Periodic retention of water followed by excretion have also been proved to be a characteristic of the metabolism, which suggests a phase of post-pituitary dominance, followed by a phase of thyroid dominance. Fluctuations in the calcium balance as well as in those of the nitrogenous compounds, all converge toward the same conception.

Most recently, Herman Zondek has reported some findings on the chemistry of manic-depressive insanity which are most interesting. Because of a number of different considerations, Zondek was instigated to work with the conception that variations in the bromine content of the blood are involved in the genesis of cyclic or manic-depressive insanity. He found, to begin with, a marked diminution of the bromine content of the blood in manic-depressives submerged in the depressed phase. He treated forty examples of such melancholia with small doses of bromine, successfully. Then he reported that he had discovered in the pituitary a new hormone containing bromine, in the same way that the thyroid hormone, thyroxin, contains iodine. A water-soluble preparation of this bromine-containing pituitary hormone induced fatigue and apathy, a tendency to go to sleep, in experimental animals.

Upon the basis of these observations, Zondek has elaborated a new view of the nature of sleep, the chemistry and chemical control of which is still a mystery. As sleep begins, the bromine hormone moves to different parts of the brain from the pituitary gland, for example, to the medulla oblongata. And during sleep the pituitary loses most of the bromine hormone. During wakefulness, bromine again reaccumulates in the gland until a concentration is reached which induces sleep. With the onset of sleep, the bromine hormone again is transported to the different vegetative centres of the brain.

Sleep and wakefulness may then be regarded as a state of balance or imbalance of bromine and iodine metabolism in the brain. This would include a shift of the specific hormone of the pituitary to the metabolic centres, where the work of anabolism, the upbuilding and reconstruction of fresh synthetic material in the brain cells as well as the others of the nervous system is done. A great deal of corroboration will have to be produced before this idea can be accepted. At any rate, it rehabilitates the importance of the pituitary for the problem of hibernation and sleep once postulated by Cushing and others. That bromine is as significant for the pituitary as iodine for the thyroid might have been suspected from the fact that the pituitary contains much more bromine than any other organ, and more than fifteen times as much as is present in the blood, and more than ten times as much as is found in the brain. When we understand the

control of the iodine-bromine balance in the brain, sleep may be abolished as a wasteful habit.

The Relation of Bromides to Brain Colloids

Now, in this connexion it is most interesting that certain researches by Wright, followed later by those of Lang, have seemed to indicate that bromine treatment changed the symptoms of manic-depressive or cycloid insanity into those of dementia praecox. They achieved the effect by feeding large doses of bromide, as much as one hundred to three hundred grains in twenty-four hours, while studying the action of large quantities of the drug in every type of insanity. About 75 per cent of the patients were improved, particularly the maniacal ones. The improvement was emphasized by the fact that one nurse became able to manage those who had hitherto required the combined efforts of four or five nurses to bathe and dress them. Violent patients were quieted and became sufficiently interested to assist in the ward work.

Bancroft, developing the original ideas of Ludlum, has attempted to explain these effects of bromides in manic-depressive insanity by a consideration of its possible actions upon the protein colloids of the brain. Ludlum revived a theory of that greatest and most clear-thinking of all physiologists, Claude Bernard, that anaesthetics used in surgical operations, such as ether and chloroform, produced their results by *coagulating* the proteins of the brain. Alcohol also might be credited with causing the same effect. The bromine ions have an opposite effect, a *peptizing* action.

The coagulation of a protein colloid may be visualized by adding alcohol to some egg white in a test-tube. The egg white, which is a typical colloid, representative of the protoplasm of brain cells, becomes opaque and flaky as if it were boiled. But in the brain, said Claude Bernard, this effect is reversible. On withdrawal of the alcohol, ether, or chloroform, something reverses the effect, and the egg white returns to its original liquid, translucent condition. The latter state is referred to as 'peptization'. To peptize is the antonym of to clot or to coagulate. Coagulation and peptization are thus contrasted as opposite states of the brain proteins. The liquefaction of gelatine with heat and its solidification with cold also illustrate the difference between peptization and coagulation.

Colloids are said to be coagulated or clotted when their particles become larger, and to be peptized when their particles become smaller. When the particles of a colloid coagulate and become larger, the whole substance becomes more viscous and approaches the solid state. When the particles of a colloid become smaller, it becomes less viscous and acts more like a liquid. Egg white in the liquid state is a perfect example of a peptized colloid. Boiled egg white is the type of coagulated colloid.

The reversibility and antagonism of coagulation and peptization *might* account for the contrasts of mania and melancholia in cyclic insanity, as different degrees of peptization and coagulation of the brain cells. But Bancroft thinks that coagulation of the brain protein makes for cycloid insanity, while peptization insanity is dementia praecox or schizophrenia. The bulk of the evidence is against any such oversimplified views of what must be most complicated disturbances of brain chemistry. Rather do a host of observations point to dementia praecox as an abnormality of the iodine-thyroid metabolism of the brain, and manic-depressive insanity as affection of the bromine-pituitary metabolism.

The Chemical Prevention of Insanity

In the prevention of the neurasthenias and the neuroses, dementia praecox and manic-depressive insanity, problems of the most tremendous importance economically as well as socially and personally, knowledge of the relation of food to the endocrine glands, the brain and the nervous system, will play a great part. More than one in six of all hospital beds in the United States are constantly occupied by schizophrenes. Manic-depressives contribute a large proportion of the yearly quota of suicides. Neurotics and neurasthenics daily commit acts on the border-line of insanity which are most expensive to themselves and to society.

By anticipating the effects of an insufficiency of iodine- and bromine-containing foods, and of the amino-acids necessary for the manufacture of the thyroid and pituitary hormones, much might be accomplished during infancy, childhood, and adolescence. An excess of calcium has been shown by McCarrison to produce an enlargement of the thyroid in birds. By taking advantage of what has become known concerning

the deleterious effects of foods of the cabbage family upon the thyroid, as well as the protective action of oatmeal against the action of poisons upon the thyroid (as has been shown by Reid Hunt in the case of acetonitrile), specific diets have been of assistance in regulating the production of thyroxin.

For the production of insanity, it appears that two conditions must be fulfilled: a certain grade of inferiority of the nervous system, associated with a certain degree of insufficiency or inefficiency of the ductless glands. The former is an inherited characteristic, there being hereditary strains of nerve-tissue-defective families. Yet even such a constitutional inferiority may be compensated and overcome by proper feeding during the growth period, particularly early infancy.

In families with a history of psychopathic tendencies, the feeding of large quantities of Vitamin B, C, and G should be carried out. Iron should be provided early, in the first few months of life, in fact. Manganese-containing foods should be emphasized in additions to the diet schedule as the infant progresses. Compounds of manganese have lately been employed in the treatment of dementia praecox. Linolinic acid and the unsaturated fatty acids in the form of lecithins should be generously provided. Infants and children suffer frequently a cholesterol deficiency which undoubtedly must affect the development of the brain and nervous system. All these are matters which can be scientifically determined and tested. It should be one of the first of the child's Magna Charta of Rights that it is entitled to the best nutrition of the brain, the nervous system, and the ductless glands as preparedness for the pursuit of life, liberty, and happiness.

Altogether, then, chemical studies of various abnormal states of bodymind, characterized by wrong thinking, disproportionate emotion, inaccurate perception, and incorrect behaviour, emphasize anew the validity of the bodymind concept. Both among children and among adults such disturbances, whether existing in their mildest forms, as the neuroses, or whether grossly apparent, as the insanities, the foundations of the maladjustment originate in a disarrangement of the chemical reactions by means of which the personality maintains its stability. It follows that, by regulating the breaks in these biochemical mechanisms, their outwardly presented phenomena of disordered behaviour may be con-

trolled. Even so-called 'psychic' treatment, treatment by means of analytic conversation and verbal education, must be considered purely supplementary to the methods which act upon the fundamentals of personality, the biochemical correlations of body and mind, which make bodymind. As time goes on, the chemical approach will undoubtedly lead to its adoption as the method of choice in the practical dealing with the problems of the disjointed bodymind. It is waste of time and energy to ask which came first, the disordered mind or the disturbed body. That dichotomy is obsolete, and should be relegated to the attic of the other medieval pseudo-problems. Looking upon bodymind as the inseparable unity which it is, the *substances* entering into their reactions are what we must build our hopes upon for the supreme control of the life and destiny of our species.

CHAPTER XIV

HUMAN CHEMISTRY AND HUMAN DESTINY

What is Character?

CHARACTER may be defined as *that which endures in the personality in spite of the vicissitudes and adventures of a lifetime.* It is that central 'somebody' of the individual who resists, controls, and integrates the flux of appetites, sensations, ideas and attitudes which make up the stream of consciousness as well as of unconsciousness. Moral strength or moral weakness are its attributes, moral problems are its domain. It is crystallized by experience, yet remains independent of it.

That definition does not imply that character is something fixed, static, unchanging or unchangeable. But it does mean that there is a something immutable in the mental interior, expressed in specific interests and emotions, in characteristic reactions and behaviours. That something is a net of habitual impulses which tend to persist and survive as a unique entity. For it is made by the inherent, dynamic, biological forces within the human being.

As such, character changes in its attempts to resist change. And so it is said to dominate or yield to the mutations of the environment. It adjusts or adapts itself to the modifying reagents, material or psychic, which play or would play upon it. And finally it evolves and matures in phases according to the laws of its own nature. Character may, indeed, be said to be the core of bodymind, and the problem of character is the core of the bodymind problem.

Now, it becomes necessary to consider the relations of climate, culture, and diet, as they modify character. By culture is meant every influence, good, bad, or indifferent, brought to bear upon the individual by the group of which he is a part. Cultural pressures work to make him use his

capacity to mould and model himself according to the set of ideals the group has accepted as what is good for him.

For man is not simply a biochemical system, nor an animal like the tiger ranging through a jungle, nor an insect of a hive depending upon his instincts. He is a biocultural organism. As a plastic protoplasm, sensitive and responsive to suggestion, information, stimulation and depression, education and direction, he partakes of social life, as well as of physical life and chemical life. That is often overlooked by those biologists who stress individuality.

All one has to do, though, is look about to see that in all our horde cultures, and in spite of all the instincts and compulsions of the herd, personalities are different. Men wear the same clothes, use the same words and phrases to make articulate their feelings, ideas, and wishes. They labour in the same work-rooms, offices, studios, laboratories, and are the slaves of the same machines. They subject themselves to the identical routines of cultural uniformity. And yet they remain different. That is obvious and unquestionable even to those who protest so vehemently and so rightly against the uniformizations of all expressions of human personality which is so characteristic of our time.

Character, moreover, subsists in a treaty with culture. Character compromises with culture, enters into deals with it, exchanges and barters. Now it is at war, now at peace with it, now in a state of the armed truce, sometimes defeated, abject, and tribute-paying, and other times triumphantly itself, even if only explosively and paroxysmally. But always and ultimately, character is an independent and not a dependent of culture.

Climate and Metabolism

The effects of climate upon character have long been objects of speculation. In his *History of Civilization in England*, Buckle (who spent ten years gathering his material for it) developed the conception that the physical agents by which the human race is most powerfully influenced are climate, food, soil, and what he capitalized as the ' General Aspect of Nature '. The action of the last, by which he designated the natural surroundings of a people, he referred to its effect upon their imagination. What is more interesting is the fact that he attempted to analyse the relation of climate

to the need for the carbon-containing foods which supply heat.

In a cold climate with little carbon-containing fauna and flora available, he argued, men would be stimulated to greater exertions to obtain their carbon. The point is still good and still arguable. As far as individual differences are concerned, Buckle had no means of even theorizing, since the knowledge of food in his time was of the most rudimentary. So he confused the effects of climate on individual metabolism with its effects upon *culture*. To-day it is known that body-mind chemistry is the link between the two sets of effects, establishing a law of relationship between climate, culture, and character.

A climatic environment consists of (1) variations in humidity —that is, water content of the atmosphere ; (2) differences in temperature, heat and cold ; and (3) fluctuations of the electrical and magnetic conditions of earth and its air envelope. These are connected with the influences of mountains and sea level, altitude and gravity, and their concomitant changes in atmospheric pressure and oxygen content. Above all, there is sunlight, with its range of vibrations within the coloured spectrum, as well as the infra-red and ultra-violet octaves. The weight of evidence confirms that the effects of climate are mediated through the endocrine glands.

Mills made comparative studies of maps of North America presenting the relative distribution in its different areas of deaths due to overaction of the thyroid—exophthalmic goitre —deficient action of the insular pancreas—diabetes—and exhaustion of the bone marrow—pernicious anaemia. A survey was also conducted of variations in climate in these different areas, with special reference to the occurrence of storms and day-to-day variability of temperature. It was found that these three diseases of the ductless glands and metabolism are most prevalent in two great districts of the United States, one located around the Great Lakes, and the other taking in the Pacific Northwest. The death rates for these typical glandular metabolic diseases are much greater in these regions than in the Southern States or the Far North.

As climate maps show that the Great Lakes country has the most marked storm frequency and the greatest daily temperature variability in the North American continent, it is legitimate to conclude that such ups and downs of climatic

condition are responsible for the greater morbidity and mortality from the glandular and metabolic diseases. In other words, the glands involved, the thyroid, the adrenals, the pancreas, and so on, are subjected to climatic influences —stimulation or depression—in a most fundamental way. Glandular and metabolic breakdown naturally would tend to occur more often where there is the most powerful climatic drive. The important principle involved is established that the major effects of climate upon the personality are mediated through the glands of internal secretions. A stimulating climate is one which stimulates the glands of internal secretion in definite ascertainable ways. Depressing weather is one which depresses the glands of internal secretion in observable, measurable ways.

One other influence of climate that is beginning to be seriously considered and studied is that of the degree of ionization of the air. The degree of active electrification of the atmosphere has been shown to have an effect upon the sensations of sufferers from such diseases as gout, rheumatism, arthritis, and neuritis. They experience more pain when there is an increase of the positive ions of the surrounding air they breathe and which also plays upon their skin. Normally the air contains about 50,000 to 100,000 ions per cubic centimetre. Dessauer has invented a machine which generates tremendous concentrations of ions—twenty million to the cubic centimetre. It is being used in experimentation on the curative effects of ionized air.

The relation of storms to the atmosphere is undoubtedly traceable to changes in its countless electro-magnetic ions. This variability in degree of ionization must have much to do with the interesting relations of storminess to the ductless glands and metabolism emphasized by Mills. As far back as the practice of Hippocrates, the medical profession has been challenged to explain and use the indubitable effects of sea or mountain air, the sea trip taken for metabolic alteration, the change of scene. Nowadays when we view the air not simply as mixtures of nitrogen and oxygen, but as billions of billions of not only nitrogen ions and oxygen ions, but also argon molecules, neon molecules, krypton, zenon, and helium molecules, we see ourselves as walking about in a constantly changing electro-magnetic field.

How complex is the problem of understanding this cir-

cumambient field of electricity and magnetism for all of us is the recent discovery of the active importance of the rare gases hitherto but no longer called the inert gases—helium, neon, zenon, krypton, and argon. These are present only in traces, in homoeopathic doses, in such traces that they were not proved to be present in ordinary air until just before the turn of the century by Lord Rayleigh and Sir William Ramsay. Though they were called the *noble* gases, they were thought to have no function in the animal body. Recent careful experimentation has shown that animals will live longer in a mixture of oxygen and nitrogen containing traces of these rare gases than in a mixture of pure oxygen and nitrogen. They possibly produce their effect by changing favourably the degree of ionization of the air. Until an instrument has been invented to measure simply and quickly the number of ions in any atmosphere, no accurate studies can be carried out of their influence upon the ductless glands and metabolism, through which they probably act. But that will come in time and put into our hands a new weapon for the control of the physics and chemistry of the bodymind.

Climate must be considered as working in combination with soil chemistry. In Tennessee, new-born colts, calves, and other animals reared where the soil is rich in mineral elements like iron, iodine, manganese, copper, and cobalt, are much stronger and more vital than those raised in other regions. Analysis of fruits and vegetables from a mineral rich region shows them to be quite different from samples grown in other parts of the country. The amount of iodine in oranges, or iron in spinach, for example, may be quite different, depending upon where they have been grown. Wheat grown in the blue-grass districts of Kentucky contains almost three times as much phosphorus as that cultivated in Wisconsin, Michigan, or Minnesota. The amount of cobalt is quite variable in different regions and soils. Cereals, fruits, and vegetables vary correspondingly in their cobalt, which occurs in largest quantity in certain limestone regions. According to Weston, the live-stock born and bred in the cobalt-rich limestone country have extraordinarily fine physiques and superior general development. Foods ought to be certified as to soil origin and chemical composition.

The great Liebig attempted to work out what might be called a *psycho-chemical interpretation of history* based upon

the conception of exhaustion of the soil by successive exploitation over a period of generations. Exportation of food from a locality would aggravate this exhaustion. The idea is serviceable in explaining the rise and fall of certain of the great nations, such as the Greek city-republics and the Roman Empire. Nitrogen and phosphorus were what specially concerned him and his interest and propaganda led to the great development of the agricultural fertilizer industry in Germany. Modern research on the variability of the mineral content of different soils tends to confirm his ideas. But a truly adequate psycho-chemical theory of history would found itself upon a summation of the effects of climatic physics and soil and food chemistry as they affect the ductless glands of different peoples and nations.

All of the constituents of an environment are indeed stimuli to the glands of internal secretion which are sensitive to them. Through their total effect, the function of a gland may be stimulated to the point of relative overactivity, within, however, the physiological limits. The thyroid, for example, functions to maintain temperature at the normal level. Heat and cold acting upon the personality over a period of time are bound to leave their mark on the thyroid. The parathyroid glands are sensitive to the light content of an environment. We know that the amount of infra-red and ultra-violet rays playing upon the earth vary during different seasons of the year in different localities and have their effect on the parathyroids. The adrenal glands are affected by heat, cold, and sunlight. The post-pituitary reacts to the humidity variations of a climate. The stimulating effect of the tropics upon the sex glands is well known. In fact, it is possible to trace the most important effects of climate upon individuality to reactions affecting metabolism through the endocrines.

Climate, then, like food, affects character through metabolism by way of the ductless glands. It must be said again, therefore, that character is a function of metabolism. That is saying that character is more or less of a constant in a personality which varies otherwise with metabolism. Metabolism is constantly in flux, for it consists of the hundreds of transactions in the chemical exchanges of the bodymind, occurring with every breath and every pulse-beat. How can it be asserted that character, that which endures, is contingent

upon metabolism, than which there is nothing less impermanent ?

The answer is that, while metabolism is like the river of Heraclitus, an unending flux in which no man can bathe more than once, it also retains the underlying stability of a great river like the Hudson. As a matter of fact, Child has compared the living organism and its metabolism with the flow of a stream and the incessant changes of its banks which yet manage to retain their form. And Roux, the German embryologist, has been enthusiastic over the analogies between the metabolism of protoplasm and the metabolism of a fire. Both comparisons are inadequate, because one is too physical, the other too chemical. If one imagines a river afire, a river of burning oil, the banks and bed of which are at once the producers and products of the combustion, a somewhat adequate image would be achieved, conveying both the stability and instability of the constant play of metabolism upon character. The living organism, the functioning personality, is, of course, infinitely more complex than any such analogy. But the figure enables one to visualize how stability may be incorporated with instability, how the apparent swirl of metabolism may be combined with the seemingly granitic congealments of character.

How can we account for the paradox ? Once again it appears that the resolution of the dilemma lies in the endocrine glands which act as both the regulators of metabolism and the stabilizers of character. Their hormones, indeed, are to character and metabolism what the light of the sun is to the earth. The radiant vibrations of the sun control the recurring cycles of the earth's life-history. They also determine that which gives its special character to any of the localities of the earth. Without the relatively steady regulating, stabilizing action of the internal secretions of the endocrine glands, there would be no underlying tendencies of metabolism. There would be no special trends of chemistry at all worth speaking of, and consequently no peculiarities of character. And as the interplay of earth materials and sun radiations makes for the differences, say, between the polar regions and the Sahara Desert, the interaction of food materials and endocrine secretions may well account for many of the differences between a Gandhi and a Napoleon.

Only one other chemical theory of personality can challenge

this conception with any show of logical consistency. That is the theory of the genes, the inheritable chemical substances which compose the chromosomes that hand on family traits. But there is no genuine conflict between the gene theory of character and the view that its fundamental lines emerge as the outcome of a long-continued interaction of food, the endocrine glands, and the nervous system. One can do no better here than to quote what Jennings has written as a zoologist concerning the relation of the genes to the hormones :

It is clear that many of the effects of the genes in development are produced through the action of the hormones that they manufacture. Particularly in later development, the hormones play a very great role. Diverse sets of genes produce hormones differing quantitatively or qualitatively, and to these differences many of the inherited peculiarities of individuals are directly due. The diverse characteristics are due originally to diversity of genes, mediately to diversity of the hormones produced by the different sets of genes.

The action of hormones reveals again that what a given set of gene produces depends not on its own constitution alone, but on the conditions surrounding it. Such a relation was revealed also in the earlier stages of development: what a given cell produced depended on the cells that surrounded it. If a hormone of a certain quality or intensity of action is present, the cells produce a certain set of structures ; if the hormone is of another quality or intensity, the same cells produce other structures. The same set of genes yields the male or the female characteristics, depending on what hormone is present. The same set of genes yields a lethargic or an active individual, an imbecile or an intelligent person, depending upon the hormone that is present. The same set of genes produces a giant or a dwarf, depending upon the hormone that is present. What hormone is present depends again under the usual condition, on what set of genes was present at the beginning ; but by operations, or in other ways, another hormone may be substituted for the one normally present, changing development. Through the hormones they produce, the diverse parts of the body affect each other's environments, altering development, causing each part to develop in relation to others.[1]

For the practical purposes of the physician, parents, educators, social-minded people, and even statesmen, the genes have to be discarded as objects at present entirely out

[1] *The Biological Basis of Human Nature*, p. 120.

of our control. Contrariwise, though, foods and the hormones of the glands of internal secretion are quite controllable. For the intake of food may be properly selected. Various glands of internal secretions may be treated and modified, to correct defects and abnormalities of character in a most satisfactorily practical way. This by no means implies that an absolute control of character through food and the endocrine glands is at present within our reach. It does indicate that a relative control by such measures is possible and has been attained.

Particularly is this true of children, who are more plastic and responsive to modifying influences of all sorts. It is also true of adolescents, who are naturally going through a period of tremendous mutation of metabolism and character. But even adults have been transformed in a most startling manner, with results that would have been considered wholly improbable only fifteen years ago. The immense revolutionary advances which have taken place in both fields, dietetics and endocrinology, during the last decade and a half, have made the achievement possible. And what has been accomplished merely presages what is still to come.

Emotional Stability dependent upon Metabolic Stability

Stability of character, then, depends upon stability of metabolism. And we may see the principle at work under all sorts of conditions. One of the first to make observations upon the working of this principle was Hammett. As long ago as 1920, he reported them in his paper entitled, 'Observations on the Relation Between Emotional and Metabolic Stability'.

Hammett began working with the idea that mankind may be grouped into two great classes as regards *temperament*, or relative emotional stability. The criterion of classification was the degree of susceptibility to emotional excitation. One class, representing one extreme, is the class of the fundamentally stable, the unemotional as they might be called, or the 'cold-hearted' people, who pursue the even tenor of their way apparently and actually undisturbed by the surrounding daily happenings. The other class consists of their opposites, the emotionals, or 'hot-headed' people, whose emotions seem set to respond to stimulation like a hair-trigger, 'with a magnitude of reaction all out of proportion to the

value of the stimulus received'. Between these two 100-per-cent types may be placed the majority of human beings, whose temperamental excitability may be stated as more or less of one or the other tendency.

Now, it has been pretty firmly established that emotional reactions are inextricably interwoven with the activities of the endocrine glands. And it might be expected that emotional stability or instability is connected with the stability or instability of production of the internal secretions involved in the emotions. All the effects of the emotions upon the digestion, absorption, assimilation, combustion, and excretion of foods and food products can be imitated by injections of different hormones. Emotions can also be artificially produced by the same kind of injections, as shown by the work of Cushing, Maranon, Berman, and others.

It can be expected, moreover, that stability or instability of the endocrine glands (and the vegetative nervous system which they regulate) in relation to food should be mirrored in metabolism. It should be possible to follow the effects upon metabolism through the variations in the substances of metabolism, the metabolites, of which a certain amount is always present in the blood. These are substances like uric acid, urea, total nitrogen and non-protein nitrogen, creatine and creatinine, sugar and cholesterol, phosphorus, calcium, and iodine.

Hammett studied the variability of the chemical composition of the blood of emotionally stable and unstable normal and insane persons, at weekly intervals. The research aimed to establish whether the chemistry of the blood constituents, reflecting the course of metabolism, would show the same stability or instability as the emotional state of the individual himself. The latter was reported by physicians having very good opportunities to observe him and decide upon his emotional condition. A coefficient of variability for each constituent of the blood analysed was worked out. Then the variability of metabolism was rated by adding all the coefficients of variability (nine altogether). The resulting figure was used as representing the total variability.

It was concluded that, while differences in variability between one individual and another might be small, there was a striking emotional difference between those having the highest metabolic instability and those having the lowest

metabolic instability. The latter were those with the least emotional instability. That is, they were relatively stable emotionally. Those with the highest metabolic instability also had the greatest emotional instability. That is, they were relatively unstable emotionally. At one extreme of the series, for example, was a male nurse, with a total variability of 129, who was of the nervous type, 'easily upset by minor occurrences, and with a continual attitude of worry'. At the other extreme of the series was another male nurse, with a total variability of 76, 'who was phlegmatic and inexcitable, paying no attention to the ordinary little vicissitudes of life'.

The stability index of these emotional metabolic-labiles and unemotional metabolic-stabiles may be correlated with the different states of their involuntary or vegetative nervous system. There may be a dominance of one or the other of the two components of this system, which consists of the two antagonistic divisions, the sympathetic system and the vagus or parasympathetic system. The individual whose endocrine glands are so functioning that his sympathetic system tends to control will be metabolically unstable and emotionally unstable. He whose endocrine glands make for a vagus dominance has maintained for him a firm restraining hand against any disturbing influence. He will be better protected and remain, metabolically and emotionally, relatively untouched by the environment.

In practice, such one-sided predominance of one or the other systems occurs only among certain types. Among others it is more common to find viscerally irritable and viscerally calm people. The viscerally calm people possess both sympathetic and vagus components which resist effectively attempts to disturb their equilibrium. So they remain stable emotionally and metabolically. In most people the vegetative nervous system and the endocrine glands tend to remain balanced.

Studying the effect of excitement, Hammett was further able to demonstrate the possible effects of irritation on the metabolism of two different groups of animals, correspondingly to the chronically excitable and emotional and the usually unexcitable and unemotional human beings. He took two groups of albino rats of the same ancestry and brought up under exactly similar conditions. One group was systemat-

ically petted and gentled when handled so that after a time each animal could be held in the hand without any special attempt at quieting their natural fright and irritability when removed from their cages. The other group was roughly handled when brought out and purposely irritated. Then the parathyroid glands of both groups were removed.

The removal of the parathyroids results in a disturbance of metabolism with a marked increase of sensitivity of the vegetative nervous system, in both the sympathetic and vagus components. Quite different effects were observed in the two groups of rats. In the roughly handled animals, the operation tended to increase an already existing irritability and instability of metabolism. Such was not the case for the gentled and petted animals. It was found that 79 per cent of the animals which were allowed to remain fearful and angry died within forty-eight hours after the operation. Four out of five of them died of the form of poisoning by metabolic by-products known as 'acute parathyroid tetany'; while of the animals in whom fear and anger had been abolished by gentling and petting, only 13 per cent, or less than one out of five, died. These results throw light upon the mechanics of psychotherapy.

Now, the striking effect of gentling is upon the tone or *tonus* of the muscles. The tonus measures the degree of contraction of the muscles while the individual is apparently at rest. It is an indicator of his state of tension or relaxation. Tense people are those whose muscles are contracted even when they are not actively using them. The tonus of their muscles is high, as can be objectively demonstrated by certain tests. Relaxed people are those whose muscles are relaxed when they are not voluntarily active. The tonus of their muscles is said to be low. Mental tension is invariably accompanied by muscular tension. Mental relaxation tends to be followed by muscular relaxation. Muscular relaxation is used as a means of obtaining mental relaxation.

The substance creatin, occurring significantly only in muscle, is correlated with muscle tone. That which tends to increase muscle tone tends to increase its creatin content. The creatin content of muscle is reflected in the creatin content of the blood. And if the creatin content of the blood gets high, it overflows into the urine and produces the condition of creatinuria. We have, then, in the measurement

of the creatin content of the blood and urine of an individual an objective method of estimating his muscular and temperamental tension.

In the most extreme state of muscular and mental relaxation known, the catatonic stupor of dementia praecox, the lowest percentage values of creatin have been reported. As they emerge from their stupor, and the remarkable flaccidity of their muscles begins to be replaced by some degree of tonus and signs of activity, the creatin percentage of the schizophrene rises until it may almost be doubled. Individuals who are nervous and the tone of whose muscles is above the normal (jumpy people), hyperthyroid people, parathyroid deficient people, women in a state of tension before the menstrual period, all show a creatin output corresponding to an increased quantity of creatin in the muscles and blood.

Creatin has been stated by Hammett to be an end product of the metabolism of muscle protein associated with the condition of muscle tonus. There is also a correlation of the sugar phase of muscle metabolism with the production of creatin. It is obvious that, in view of these facts, the creatin content of meat and high protein foods must be considered in dealing with the problems of character in individuals who are normally tense, and suffer because they overreact to situations.

These observations of Hammett have been amplified by the work of Lloyd Arnold. Beginning his studies by metabolic examination of individuals subject to attacks of hay fever, hives, or migraine—obviously sensitive or sensitized people—he was led, as so many others have been, to the bilateral classification of human types which have been universally recognized. These two types really represent extremes of certain glandular tendencies, and most human beings belong in the range between. One is the linear, long, tall, and thin. The other is the lateral, wide, stocky, and heavy. Emotionally they correspond to the schizoids and cycloids described by the psychiatrists. And, as regards their weight and organ sizes and shapes, to the micro-splanchnics and macro-splanchnics of Viola.

Regular daily observations were made upon the various constituents of the blood chemistry of these individuals. Observations were made upon their spontaneous activities. Their reactions to variations of temperature were studied, and so on.

It was found that the heavy, stocky people were the stable people—stable chemically, stable emotionally, stable as regards their daily lives. They tended to be routineers and to settle down quickly to the daily regimen. They were not easily bored, but were satisfied to eat, sleep, and read. They were not made uncomfortable when transferred from a hot room to a cold room, or vice versa. Their metabolism tended to be low, and remained about the same from day to day as did the chemical constituents of their blood.

On the other side of the ledger, the tall, thin people presented a direct contrast in their reactions in every respect. They showed a tendency to a high metabolism, which, however, varied from day to day. The data for their blood chemistry, taken every morning, were never constant, but fluctuated within certain limits. They were readily excitable, and became uneasy, bored, or annoyed, with the greatest facility. When placed in a hot room, they exhibited a lessening of weight the following day. They would not stay put, but were always up and about, looking for something to do. The correlation of unstable metabolism, changing body chemistry, and fluctuating mood and activity was marked.

It was concluded that these latter, the environmentally sensitive people, whose bodies undergo constant change, are the energetic, enterprising, forceful, leading members of groups. Because they themselves are changing, they tend to introduce changes into their surroundings. The variations of their functions and chemistry when charted on paper suggest, in their up-and-down characteristics, the peaked profiles of mountain ranges. For evil or for good, they are the catalysts of human society, for they cause things to happen. Exaggeration of the type characteristics swings the individual over into the group of genius, on the one hand, or into that of insanity, on the other. The tension and mutation of modern life in a highly organized civilization test and develop this group more than the stable, stocky people.

Natural Conservatives versus Natural Radicals

In his magnificent essay on ' The Conduct of Life ', Emerson affirmed that the conservative is a conservative in virtue of the defects of his constitution. That was a superb intuition extracted from the wisdom of unconscious perceptions which enabled Emerson to speak like the grand prophet he

was for all coming generations. Yet an intuition can only be regarded as an opinion of synthetic judgement. It can only have the status of a messianic epigram until it is reinforced by data of a more factual validity.

The principle of metabolic stability or instability, now thoroughly established as characteristic of the chemical constitution of any personality, provides a solid objective background for the Emersonian dictum. The presence of metabolic stability, for which Cannon has suggested the name of ' homoiostasis ', may be counterpoised with the possibility of metabolic instability which might be called ' heterostasis '. And thus we may arrive at another, but more fundamental, bilateral classification of human beings, the chemical classification. Two great arch-types emerge with a number of contrasting peculiarities of chemistry, character and destiny.

These two great classes are composed of those who group themselves as the ' homoiostatics ' and those who are the ' heterostatics '. The homoiostatics are those with an inherently stable metabolism, whose blood chemistry, tissue chemistry, brain and nervous chemistry tend to remain the same from day to day, week to week, month to month, as can actually be proved by detailed scientific examination. The heterostatics, on the other hand, are those whose metabolism is essentially unstable, and whose blood chemistry, tissue chemistry, emotions and mentality change, and sometimes with the most startling rapidity, from day to day, from phase to phase, with the most marked reverberations in the general attitudes and moods. The homoiostatics are the temperaments who persist in their status with an inertia that is characteristic. The heterostatics tend to react against fixity of any sort, whether in love or business, politics or religion.

Now, nothing is more certain than that the intellect, the reasoning intelligence of a man, is motivated and guided by the demands of his organic processes and needs. The personality of the metabolically stable homoiostatic is that of the natural conservative. The personality of the chemically unstable heterostatic may be described as the natural radical. The true conservative may be said to have a fairly rigid body-mind chemistry. It responds to the forces of change with a scarcely perceptible compensation, and the situation remains unchanged. Because all things, within himself, tend to be the same and remain the same from one end of the moon's

cycle to the other, he is well content to allow all things outside himself to remain the same. Since he is fairly perfectly adapted, quite satisfactorily adjusted, in the deepest, most secret depths of his being, why should he not prefer to remain conservative, really preservative, in all his social attitudes, for he realizes unconsciously, if not consciously, that mutation, revision, revolution, are for him unnecessary and finally detrimental? In the face of the prospect of change, he will, indeed, become reactionary.

The heterostatic, on the other hand, is constitutionally a revolutionary. A rebel, a revolter, a progressive, he must be and wills to be, because change is the essence of his own dynamics. In their extreme types, the homoiostatic conservative may be compared to one who walks on a platform or, as he himself proudly says, 'with his feet on the ground'; the heterostatic to one who is balancing himself on a trapeze with the point of one toe. The natural fluctuations and permutations of his chemistry render the heterostatic plastic in his responses and so he comes to require a certain plasticity in his stimuli, that is, in his environment. He is congenitally discontented, advancing, pioneering, and his discontent contrasts sharply with the unconscious complacency of his antagonist.

So it appears that even political traits of character, and their concomitant economic and social attitudes, may be determined by the fundamental, underlying tendencies of bodymind chemistry. And that is a principle the Marxians, with their economic determination of history, might ponder. The metabolically unstable, relatively sensitive and plastic, the tense and introverted, produce the natural leaders of political and social change. The metabolically stable, rigid personalities, extraverted and contented, tend to maintain the traditions of their class, nation, and personal activity. The struggle of the classes is the universal and eternal conflict between the homoiostatics and the heterostatics.

The Stability Index

Now, though it is clear that all human beings may be grouped into the two great classes of the metabolically stable and the metabolically unstable, it by no means follows that all the members of the latter can be lumped together as possessing identical characteristics. Metabolic instability is

an end result of a variety of chemical mechanisms. These can best be determined by studying how different types of metabolic constitutions react to methods which can be diagnostically employed to recognize them. In turn, a set of information emerges which is most valuable from the standpoint of prevention and treatment of those manifestations of character, personality, and ill-health which are by-products of unstable chemical conditions in the bodymind.

To measure degrees and kinds of metabolic instability, it becomes necessary to introduce an element of disturbance which is statable in terms of units agreed upon as the standards of measurement. The bodymind is a self-regulating system which tends to preserve itself against upsets of any sort by bringing its regulators into play. Consequently, the investigation of any given personality concentrates upon certain of the regulating mechanisms which act to restrain change. As they function over a measurable range, their reactions to reagents of change may be observed accurately within certain limits. In other words, the organism is jarred by some stimulus and its mode of recovery is measured. The resulting picture provides a modicum of insight into underlying tendencies and trends of metabolism which are of first-rate importance for the understanding of the individual.

The practical problem is to apply a method which is at once simple and reliable. A number of tests might be suggested to rate what might be called the 'stability index' of any personality; that is, its measurable resistance to disturbance of its chemical equanimity. A given measured amount of heat or cold might be applied, and the resultant reactions measured. Or a dose of strong light or a quantity of electricity might be used. Or a catalyst that would interfere with the usual course of the chemisms of the bodymind could be injected. All of these do figure in the daily trials of an individual's stability.

Isaac and Reiter first employed the method of catalytic disturbance by studying the effect of the injection of insulin upon a series of individuals. They measured the effect of ten units of insulin upon the blood sugar and the blood pressure, the oxygen consumption and the respiratory quotient: four variables, that can be measured quite easily and accurately. Thus a quantitative graph of the metabolic stability could be charted. Berman repeated their work with some modi-

fications and carried out psychological tests and observations of the personality types that emerged.

Generalizing the type reactions, the emergent group pictures are seen to be capable of being correlated with the degree of excitability of different portions of the vegetative nervous system. The activities of the vegetative nervous system are involuntary and not under conscious control. The cells of the involuntary vegetative nervous system are stimulators and depressors of the internal organs. These stimulators and depressors are known as the vagus and sympathetic systems. Constantly, the ductless glands are confronted with the task of maintaining a balance between these two grand governors of the viscera. The two opposing rivals struggle for dominion in the vegetative nervous system itself. The twain represent the two-party system of the cellular democracy and function throughout the bodymind in antithetic directions. Thus, the sympathetic nerves of the heart act to make it go faster, the vagus to make it go more slowly. All along the line, it has been pretty well established that wherever the vagus acts to stimulate or depress function, the sympathetic tends to reverse the effect. And the normal status consists of a state of balance between the two competitors for dominion over the most deep-seated processes of life.

Now, one or the other of the competitors may be either weakened in its influence or strengthened in its effect. If strengthening is designated by a plus sign, and weakening by a minus sign, five possibilities become apparent. The vagus may be precisely balanced by the sympathetic—the ideal state of metabolic stability—which may be designated by the symbols $V = S$. Or there may be a state of imbalance or metabolic instability, as follows:

$V+S+$ (vago-sympathetic resistant)	$V-S-$ (vago-sympathetic excitable)
$V+S-$ (vagotonic)	$V-S+$ (sympathicotonic)

He or she who has a balanced vago-sympathetic system and is metabolically stable responds to the injection of ten units of insulin with a decrease of the blood sugar by about 20 per cent, returning to normal in about half an hour. Oxygen consumption rises by about 10 per cent in a half-hour and returns to normal in about ninety minutes. At the

same time there is a slow rise in the respiratory quotient, which means that more sugar is being burned, but it quickly descends to the normal. In sum, the normal metabolically stable person is upset by a catalyst like insulin for about two hours; and then swings back to his old self. This reaction probably would hold good for a number of other disturbing agents.

The vago-sympathetic-resistant individual, V + S +, represents a small group which will not react even as much as the normal. It is characteristic of senility or pre-senility and of people who are said to be older than their years. Apathy is the constant solvent of all their emotional moods. They themselves often complain of their lack of emotion and of a consequent loss of a zest in life. They have the highest stability index and present the firmest resistance to the unit dose of chemical change. In response to insulin, the blood sugar may drop only 5 per cent, or not at all, and there will be little change in the blood pressure, the oxygen intake, or the respiratory quotient. An absolute and automatic coolness under the threat of danger or ecstasy of any kind characterizes their life reactions. They can never really be unhappy, neither can they ever be genuinely happy.

A group which is the polar opposite of these imperturbables consists of the individuals who are excessively sensitive and unstable, with irritable and labile vagus and sympathetic systems and rocking metabolism, the V — P —. They are also known as the 'asthenics' (who also tend to become the ascetics and aesthetes). In their typical forms, they present the very lowest stability index, as measured in terms of reaction to insulin of their blood sugar, metabolism, respiratory quotient, and blood pressure. The chemical background of their instability is generally an infirmity of the calcium metabolism. Normally characteristic of infancy—that is, of the first two years of life—it is a phase of development which is gradually replaced during the next five years by a condition of dominance of the vagus system. But it may become fixed and be characteristic of the constitution throughout life. A shock or a disease affecting the ductless-gland system may switch an individual who has progressed normally in metabolic development back into this class of least maturity and greatest instability and irritability.

The third class of metabolic lability, the vagotonics, present

a number of the chemical characteristics of childhood. Vagotonia is in fact the normal state of the vegetative nervous system during infancy and juvenility. And so these individuals, even when they are grown up chronologically, offer a number of the bodily and mental stigmata of infantilism, and might therefore be called ‘ infantiloids ’. Tested by the insulin reaction, they react with a marked, the most marked, fall in blood sugar, which effect is greatly prolonged. Then there is a slow, short rise in the oxygen intake. The lowering of the blood sugar is accompanied by a definite dizziness, a curious weakness, and a tendency to collapse. There are thin and fat varieties of these infantiloids, and the thin can be fattened with insulin if large quantities of sugar and starch are forced at the same time. They have an insufficient specific dynamic reaction to protein food, nor does their metabolism rise properly as a response to work or cold. The central biochemical abnormality behind all these manifestations is an unstable sugar metabolism. Psychologically these people show their infantilism by their reactions of dependency and retrogression, their sexual retardation and difficulties, and their tendency to develop phobias, obsessions, and compulsions as defence reactions.

The fourth class consists of the true sympathicotonias. While vagotonia is normally characteristic of childhood, sympathicotonia is a quality of adolescence. The endocrine changes of puberty bring about a reversal of dominance in the vegetative nervous system. And so, while the vagotonic infantiloids are individuals who have become more or less fixed at the chemical levels of childhood, the sympathicotonics persist in the dynamics of the next stage, adolescence. There is still imbalance and so metabolic instability. But the instability is of another kind. There is only a slight drop in the blood sugar after insulin injection, but there is an excessive rise in the metabolism, in the blood pressure and in the respiratory quotient. All this is because there is more adrenalin normally in the blood during adolescence than at any other time, which accounts logically for many of its emotional phenomena. These people tend to maintain throughout life certain youthful peculiarities of bodymind : they are enthusiastic, hyperactive, diffusely aggressive, and egocentric. Their stability index lies in the range just below the normal.

RANGE OF THE STABILITY INDEX

Infancy Hypersensitive	Childhood Vagotonic	Adolescence Sympathetic	Maturity Normal	Senility Hypernormal
S − V −	S − V +	S + V −	V = S	V + S +

A normal individual undergoes a certain metamorphosis in his stability index as he passes from infancy to senility. At each stage certain features of his metabolism are relatively stable. The unstable are those who fail to mature or become fixed at one phase or another of the series of mutations that are the recurrent cycle of bodymind in each generation.

Differences in Response to Foods

Food plus metabolism determines the stability index. Now, foods act upon metabolism through their effects upon the ductless glands, including the liver. But it must be remembered that each of the endocrines does not function as an isolated entity, but as part of a unique physiologic pattern —the individual personality. It is necessary always to consider the endocrine formula—that is, how the different ductless glands are constellated to make the particular bodymind configuration (or *Gestalt*, as the Germans would call it), whose name is John Smith, Tom Jones, or the Duke of Marlborough. Out of the different combinations and permutations of overactivity and underactivity possible among the major ductless glands, the various types of human personality emerge, with their differing degrees of metabolic stability.

Clinically, these variable types of endocrine personality may be recognized in a manner comparable to the solution of a Chinese cut-out puzzle. The various features of the physique, chemique, and psychique, as well as the behaviour and character, of the individual at first seem a jumbled, unrelated mass of details. Certain characteristics are then seen to be collaterally related to the degree of activity of one endocrine gland or another, seem to cohere and stand logically related. In the end, without necessarily putting *all* of the constituents of the puzzle together, the underlying glandular mechanics of its appearances become apparent. The endocrine formula then may be submitted to the test of therapeutic control—the test of how the individual will react to

procedures which heighten the function of his most dominant or least efficient gland. In other words, we can test metabolic stability by testing glandular reactions which tend to upset it.

Other, more localized, chemical conditions also affect the response to food excesses and deficiencies. These may serve to explain why different individuals, like different species of animals, react differently to the same diets. It is known, for instance, that the two vegetarian species of laboratory animals, the guinea-pig and the rabbit, differ strikingly in their susceptibility to scurvy. In the guinea-pig, scurvy may be induced at will by withholding Vitamin C. In the rabbit, mere deprivation of Vitamin C will not produce scurvy except after a long time. Or the vegetarian guinea-pig may be contrasted with the carnivorous rat. McCollum was the first to describe the rather amazing fact that the same diet which provokes scurvy in the guinea-pig will result in the polyneuritis of beri-beri in rats. But the latter's bones will show the lesions of scurvy.

Kollath was able to induce in the rat the complete clinical picture of scurvy with haemorrhages, with the foods which produce it in the guinea-pig, by making only one change in the diet—substituting peanut oil for the cotton-seed oil usually employed in the diet to evoke scurvy. If, now, he added alkaline haematin to the peanut oil, there was a return to the original conditions—haemorrhagic scurvy no longer occurred, but the neuritis of beri-beri, as happened with the original cotton-seed oil diet. The alkaline haematin catalytically oxidized the unsaturated fatty acids of the peanut oil and so transformed it into the complete homologue of the cotton-seed oil, with similar effects. Just how the unsaturated fatty acids created a greater demand and need for the Vitamin C is not known. But the moral of the observation is that the mere presence or absence of catalytic oxidizers in the intestinal tract (such as might be produced by certain bacteria as well as be a part of the food intake) will make all the difference in the world as regards the metabolic stability or instability of the personality.

Kollath and his collaborators go further. Upon the basis of these observations concerning what might be called the *relativity* of any diet, they contend that beri-beri and scurvy are really simply different expressions of the same underlying

disorder of metabolism. In other terms, these are not pure vitamin diseases, the vitamin deficiencies being of importance only in relation to other minor defects of injurious excesses of other elements of the dietary. Almost twenty years before McCollum and Kollath's work, Darling observed among African negroes a definite variation in response to the same defective diet : in one group of men beri-beri appeared, while scurvy was the result in another group.

The individual is not just a chemical system, but a personality with a chemical history and a chemical past, present, and future. Depending upon what food deficiencies or excesses have exerted their influence in his ancestors as well as in his own experience, the tendency to metabolic stability or instability—translatable as stability or instability of character—will be determined. This principle, used in conjunction with the principle of the endocrine formula, explains the variable clinical pictures of faulty human metabolism : their similarities, dissimilarities, and irregularities, seen in the course of different food and glandular syndromes. The classic example is the fact that scurvy does not necessarily return in one who has had the disease even though the diet remains the same. A sort of immunity has been established because of a change in metabolism.

These principles should be remembered by those who attempt to experiment dietetically upon themselves. The possibility of injury to one or another of the endocrine glands and so to the total metabolism should always be seriously considered. A number of typical histories of such effects might be cited. One woman, to cure herself of an acne eruption of the face and to bring down her weight, put herself upon a diet. First, she reduced the fats to the point of total omission, then she left out meats and other protein-bearers, until finally she was existing on vegetables alone. At the end of eight months she returned to the usual mixed diet. But certain definite consequences appeared which pointed to injury of several of the ductless glands. Her weight, which had gone down from 133 to 113, rushed up to 144. Her hair suddenly became white, her nails soft, her skin dry, and her scalp scaly. She, who had previously been strong and energetic, became nervous and neurasthenic, with her blood pressure quite low and a corresponding fatigability and lack of vitality. Examination demonstrated definite

evidence of injury to the pituitary gland and the ovaries. Another woman put herself upon a diet of orange juice and coffee in an effort to reduce weight. Her weight decreased twenty-five pounds, but at the same time she developed a goitre, a low basal metabolism, and a number of the signs of thyroid deficiency. She was constantly sleepy and dull, did not perspire, felt cold, lost all sexual feeling, and her skin had lost all attractiveness she previously possessed. When the condition was corrected by measures directed to increase the efficiency of the thyroid, including a special diet, the goitre disappeared, and good health was restored.

Other histories might be cited of specific injury to the parathyroids, the thymus and the adrenal glands, as well as the sex glands. The careful analysis of such histories has been most useful in throwing light upon the relation between the particular endocrine and the dietary defect.

Upon the basis of the individual endocrine formula, it is possible to predict what glands will break down under dietary deficiencies, and also which can be most assisted by specific foods.

The Formula of Destiny

Some years ago, Einstein, the magnificence of whose intelligence entitles him to an opinion on all cosmic questions, expressed himself concerning the bearing of endocrinology on the problems of free will and destiny:

> I agree with Schopenhauer: We can do what we wish, but we can only wish what we must. I am not a psychologist, but it seems to me evident that physiological factors, especially our endocrines, control our destiny.
>
> Our future is predetermined. . . . Without a doubt my own career also was determined beforehand by a multitude of factors over which I had no controlling power whatsoever, determined first of all by those mysterious glands wherein Nature, as in a laboratory, prepares the true elixir of life; namely, the hormones of internal secretion.

Human destiny has been the theme of much prose and poetry. The dogma has been boomed that to modern science there is a mechanical single-tracked one-way street for every human life. Routed inevitably from start to finish, there was nothing much that could be done about it. There is no such inevitability of Fate. There are no written injunc-

tions in a Book of the Gods which have to be carried out to the last letter. Even modern physics permits a logical case for a certain amount of freedom.

Yet it is true that the general lines of each man's life are pretty well settled in the chemical nature of the soil in which his personality flowers. Every character is the outcome of at least three interacting sets of chemical substances and physical conditions: those of the seed, the soil, and the surrounding atmosphere. Their action is visible in its most obvious form in the flowering of a plant. Seed, soil, and circumambient atmosphere, all are acknowledged to play their part. They constitute the formula of destiny.

The seed, a package of chromosomes and their constituent genes, is a carrier of potential chemical reactions. The latent chemical possibilities of the chromomeres of plants are realized as sunflower or pumpkin, orchid, violet, potato or tomato. Excepting the drastic malformations producible in fruit-flies by previous treatment with X-ray or radium, nothing to date can be done to shift significantly the orderly unfolding of species characteristics. If the word Fate is applicable anywhere, it is to the seed. For in the seed, at any rate, is written the *limitations* of what is to be. And fruition often fails to attain the range of the seminal possibilities.

The seed grows in the soil. And the nature of the soil, the chemistry of the soil, is the primary limitation for the full efflorescence of the seed. The acidity or alkalinity of the soil, its content of moisture, of nitrates and phosphates, of iron and manganese, will affect all those differences in size, shape, colour, resistance to injury, vitality, longevity, and reproductivity which are characteristic of the species. They can be controlled by the addition and manipulation of fertilizers, so well known to the modern agriculturist.

The same principles hold true for human beings. But in human development, as in that of all mammalians, seed and soil have become inextricably intertwined. The human seed, the fertilized ovum, undergoes the earliest important part of its development in the relatively fixed soil that is its mother's womb and blood. But even the blood of the mother is subject to chemical variation. After birth, the soil of the human life becomes a combination of the endocrine glands it has made and the food which it ingests. Both of these are subject to deficiencies and excesses. And so, even the

human personality grows to maturity in a more or less variable soil.

In addition, the surroundings, the atmosphere, the great air envelope of the earth in which all land creatures swim, with its content of temperature, moisture, barometric pressure, and the whole range of electro-magnetic vibrations (including heat, light, and electricity), all influence the evolution of the seed. Its growth and maturation are just as dependent upon sunlight, for instance, as upon the constituents of the soil. In the human being, all these components of the surrounding atmosphere also play their determining role, because each affects metabolism through special effects upon the endocrine glands. But besides, the psychic contents of the surroundings, the presence or absence of emotionally stirring, disturbing, depressing, or inhibiting influences and persons, are of the most tremendous significance. Representing the symbols and agents of culture, they make of the human animal the biocultural being whose differences from the other animals are so great as to deserve classification of him as a super-animal.

Seed, soil, and surroundings, then, determine those interdependent features of the personality: physique, chemique, psychique, character, and behaviour. Together they constitute the Destiny of the individual as opposed to the part played by Chance in his life. The length of Cleopatra's nose, the craving for chocolates of the cold, unscrupulous, analytical Napoleon, the strange amours of the Elizabeth Tudor who was Queen of England, all were the products of the powerful deep-lying forces beyond their ken and control. Once more the student of human personality is faced by the dilemma of mechanism versus free will.

It is an ancient problem, this one of free will versus the doctrine that all human behaviour is predetermined. The physician therapist is impressed and convinced by the developing detailed knowledge of how seed, soil, and surroundings, interacting, make and break individuals in all their expressions. Although modern physics and metaphysics have made possible belief in a certain minimum of free will and have made it at least barely respectable in scientific society, knowledge of the effects of foods and the endocrine glands makes it more and more impossible, in practice, to consider it seriously for the unhealthy, unbalanced, subnormal human being. Freedom of action, if it is to be imagined and admitted

at all, can be conceded only for the obviously healthy and normal and absolutely denied for the obviously neurotic, the imbalanced, the idiotic, the demented, and the maniacal.

The ancient Roman law first recognized the principle of causality in character when it distinguished the responsibility of the mentally well from the irresponsibility of the mentally ill. In two fields, different conceptions of moral responsibility, mitigated or unmitigated, have had enormous practical consequences. First came the religious, which involved the question of the salvation of the soul, with corresponding rewards and punishments in heaven and hell. Closely bound with it has been the attitude to the criminal as well as to the sick, including the problem of the penalty for offences against persons and laws.

Among the Palestinian Jews, who influenced Christian creed and conduct so profoundly, there were three sects whose disputations are recorded in the Talmud. There were the Essenes, who were absolute fatalists and denied any possible liberty of behaviour. Against them placed themselves the conservative Sadducees, who preached a 100-per-cent freedom of initiative and responsibility. The compromisers were the Pharisees, who believed in judicially mixing the two attitudes. Because they were the liberals, the Pharisees were despised by the combatants of the extremist doctrinaires more than they hated one another.

Accepting naïvely the notions of heaven and hell, the Greek Christian fathers, from Origen to Chrysostom, never even questioned the dogma of free will. Augustine made the dogma the centre of a belligerent controversy which lasted for almost a thousand years. Out of it were generated persecutions and ideas like salvation by faith and partaking of the Grace of God, as well as salvation by works, and the voluntary choice of the side of the angels or Satan and his cohorts. In the domain of crime, the conception of free will was used to bolster instinctive retaliation and vindictive punishment in the name of justice.

No one who has ever looked upon a cretin or a pellagrin and observed the effects of the proper administration of thyroxin to the one, or Vitamin G to the other, can swallow the doctrine of free will pure and unadulterated. Rather does he become awed by the onflowing consequences of chemical destiny that neither the most intense auto-suggestion nor

tense resolution can dam. Yet we are compensated for our loss of belief in a doctrine of free will by the powers of control that scientific knowledge and the principle of causality puts into our hands.

Not that it follows that man must look upon himself as a mechanism pure and simple. But so many conditions of adequacy of diet and efficiency of the endocrine glands—plus the tangible contributions of the environment—must be fulfilled before truly rational, intelligent, balanced behaviour is possible. Only an attitude of the most humane tolerance for all aberrations of human conduct is possible for him who is acquainted with the vast mass of chemical data on the causation aud control of human behaviour.

The Future of Character Chemistry

Never at any time in the history of civilization has culture been so advanced and complex as in our time, and never has there been so much mental disease, crime, insanity, and degeneracy. No single cause, of course, can account for the increasing unhappiness of man, that has accumulated in direct proportion to the increase in his own numbers and in a certain ratio to his increased command over the forces of nature. But the evidence is strong that no minor factor in his decadence has been the denaturing of his food and the deprivations of an imbalanced diet. How much that factor can explain the increment of unbalanced, irresponsible, inferior problem people of every sort in our midst, some attempt has been made to set forth in the preceding chapters. Certain of the medical histories cited have shown how the most remarkable transformations of character and personality have been achieved by means of treatment of the endocrine glands aided by modifications of diet.

When Marinetti, the inventor of Futurism, proposed that the whole soul of the Italian people be made over by the abolition of spaghetti, vermicelli, and macaroni, he was ventilating an idea which will be regarded as a mere commonplace in another generation. Yet it must be emphasized that no fundamental change can be brought about by the mere pursuit of some unscientific fad preached by some one who has discovered a diet to fit his own personality and thereupon sets it up as a universal religion of food for everybody. Only the realization of the significance of individual variations in

the endocrine glands in relation to different kinds of foods, and the corresponding construction of dietetic programmes, will bring about a definite improvement in the chemical constitution of the human race, which is the only practical permanent reform and revolution, apart from the claims of eugenics.

Great groups of people can be assisted to an understanding of the importance of the prevention of partial dietetic deficiencies. Education of nations concerning the dangers of denaturization of foods is a necessity. But when it comes to individuals who are seeking the maximum of personal health and efficiency and the prevention of degeneration, only detailed study of the peculiarities of their metabolism and an understanding of their chemistry, based upon the way their endocrine glands are functioning, will bring about the optimum results. It has been definitely shown in animals that there is an increase in longevity, activity, and reproductive power with the best diets. There is no reason why the same effects cannot be achieved for human beings by the application of similar methods, but with emphasis upon special personality requirements and differences.

In every ramification of human activity the progress of scientific knowledge has been followed by obsolescence of the attitude of *laissez-faire* and the banishment of the defeatist doctrines which would 'leave things to Nature'. Nowadays, that kind of 'naturalism' is as medieval as 'scholasticism'. In every department of human activity, from the manufacture of power to the alleviation of childbirth, 'Nature' is being superseded by the introduction of methods and ideas forced upon human beings interested in outwitting the punishments of insufficient knowledge. Besides, as a matter of principle, nothing should be left to 'Nature'. We all live in a state of culture in which the natural is continually being replaced, not by adulterated products, but by an entirely superior substitute. Those who fear interference with 'Nature' invite a renaissance of the age of cave and candle.

What people have always meant by Nature, *à la* Rousseau, has been a state of traditional rustic dependence upon the products and parasites of the soil, field, forest, and jungle, with a corresponding reliance upon the voice of instinct and custom. That attitude was accompanied by the idea that

doing things as they always had been done was a good enough formula for the solution of any of the problems of the human race. When about a generation ago, artificial infant feeding upon a scientific basis was introduced, a great hue and cry was set up that millions of children had been raised for thousands of years by the good old methods. There was no real need for the new-fangled notions, it was shouted, by those who opposed the introduction of anaesthetics in obstetrical practice. Nevertheless, the movement for the careful regulation of the feeding of children continued to grow ; until, nowadays, the diet and growth of children are supervised at regular intervals by those fitted to see that a complete and balanced ration is being fed to produce the most favourable development of the whole personality.

The results have been of the best because there can be no doubt that the properly fed children of the post-war generation are healthier, better built, more intelligent, more beautiful, more resistant to disease, and, on the whole, superior specimens of humanity as compared with their predecessors. Not all children in all civilized centres have shared in the improvement. As long ago as 1922, the English physician Cramer pointed out the facts concerning the social and psychological, as well as physical, sides of the nutrition problem. He presented evidence that there is a constant underlying weakness in infants not fed enough of the vitamin-rich foods, for example, which appears when the infant, grown into a child, is exposed to one form or another of stress and strain. Even an imbalanced and deficient diet in the pregnant and nursing mother tends to evoke an inferior sort of offspring, not obviously suffering from any definite disease, but distinctly below par in every way. And as the child is the father to the man, the quality of the adult population is likewise affected. These tremendously important principles can be stated in sentences, but their significance should be circulated in words of fire.

The hope of the world lies in the proper scientific feeding of children and the prevention and correction of ductless-gland defects of their personality. How much will thus be accomplished for the elimination of unnecessary maladjustment to life of great masses of the ill, the discontented, the bored, and the subnormal cannot even approximately be calculated. Many, avid for some complete overturn of the miserable unhappiness of their daily lives, never suspect that it is within

themselves, and not in the course of the stars or politicians, that the fault lies. The physiological fostering of the development of well-built personalities with strong reserves of physical energy and mental power will do more for the social well-being of any country than many economic schemes.

Not that there is any implication in this book that all of the problems of the relation of nutrition to the ductless glands have been solved. Enough is known, though, to make possible the production of healthy children, prepared for the demands of a cultured civilization. Also, enough is known to make possible the prevention and therapy of much of the disease of adults, and much of the undermining of spirit and yielding to degeneration which precedes the decay of middle age. Finally, the progress of this field of knowledge opens a vista of super-health, investment in which will mean incalculable returns in increased ability of production, splendour of life, and a superb quality of happiness that is to-day almost inconceivable.

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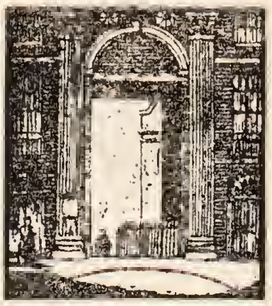

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